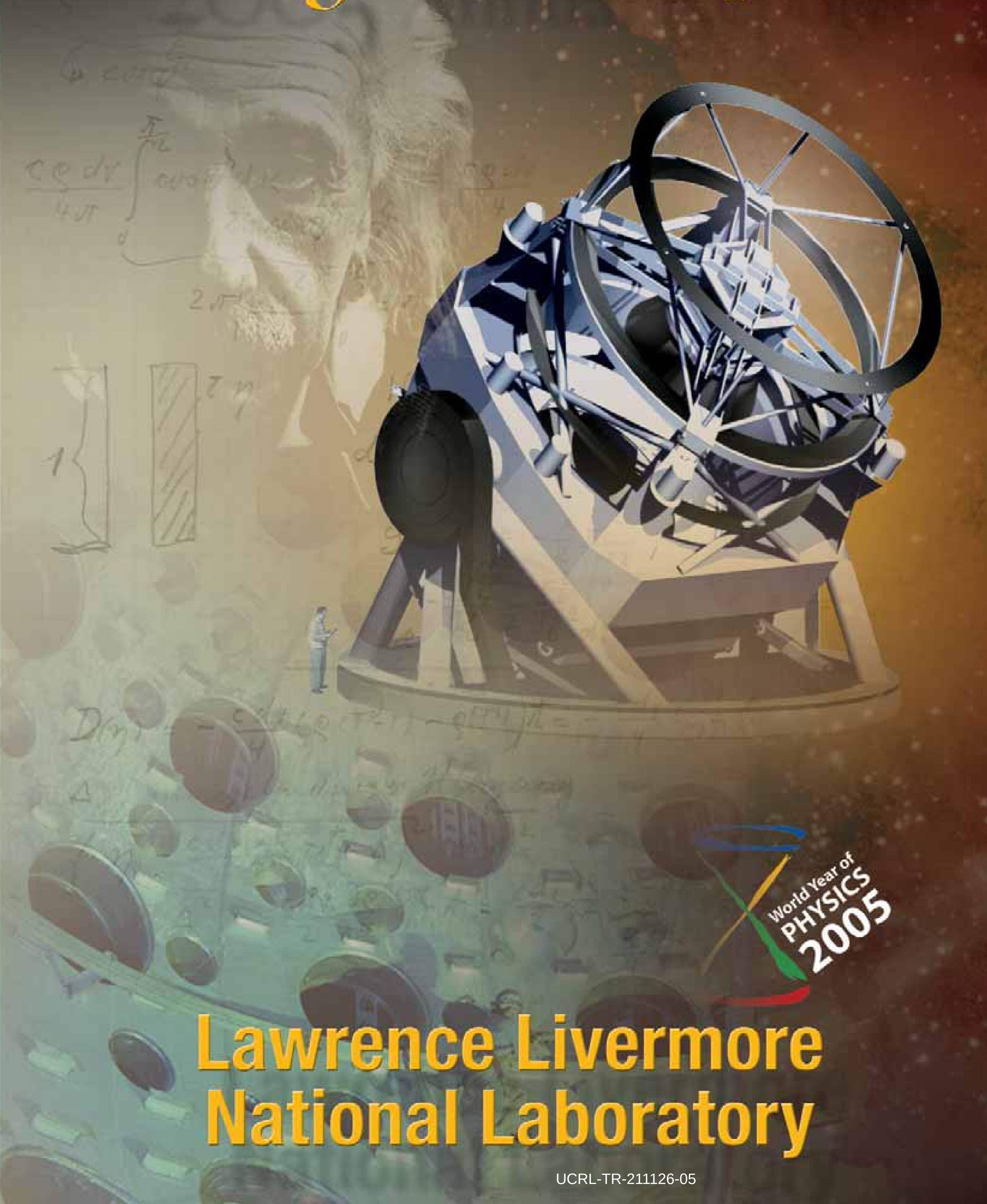
2005 Annual Report



Lawrence Livermore National Laboratory

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Inside This Annual

About the Cover

Lawrence Livermore carries on Albert Einstein's legacy with research activities to better understand the universe (the Large Synoptic Survey Telescope) and achieve fusion energy (the target chamber of the National Ignition Facility).

About the Laboratory

Lawrence Livermore National Laboratory was founded in 1952 as a nuclear weapons research facility. The Laboratory has been managed since its inception by the University of California, first for the Atomic Energy Commission and now for the National Nuclear Security Administration (NNSA) within the U.S. Department of Energy. Through its long association with the University of California, the Laboratory has been able to recruit a world-class workforce and establish an atmosphere of intellectual integrity and innovation, both of which are essential for sustained scientific and technical excellence. As an NNSA national laboratory with more than 8,000 employees, Livermore has an essential and compelling core mission in national security and the scientific and technical capabilities to solve nationally important problems.

Lawrence Livermore National Laboratory

2005 Annual Report

A Message from the Director

George Miller

As the cover of our *2005 Annual Report* highlights, Lawrence Livermore National Laboratory joined the international science community in celebrating the World Year of Physics in 2005, with special events and science outreach and education programs. Einstein's remarkable discoveries in 1905 provided an opportunity to reflect on how physics has changed the world during the last century and on the promise of future beneficial discoveries.

For half of the past century, Lawrence Livermore, which was established to meet an urgent national security need, has been contributing to the advancement of science and technology in a very special way. Co-founder Ernest O. Lawrence was the leading proponent in his generation of large-scale, multidisciplinary science and technology teams. That's Livermore's distinctive heritage and our continuing approach as a national laboratory managed and operated by the University of California for the Department of Energy's National Nuclear Security Administration (DOE/NNSA). We focus on important problems that affect our nation's security and seek breakthrough advances in science and technology to achieve mission goals.

An event in 2005 exemplifies our focus on science and technology advances in support of mission goals. In October, distinguished visitors came to Livermore to celebrate the tenth anniversary of the Accelerated Strategic Computing Initiative (now called the Advanced Simulation and Computing Program, or ASC). ASC was launched in 1995 by DOE/NNSA to achieve a million-fold increase in computing power in a decade. The goal was motivated by the need to simulate the three-dimensional performance of a nuclear weapon in sufficient resolution and with the appropriately detailed physics models included. This mission-driven goal is a key part of fulfilling Livermore's foremost responsibility to ensure that the nuclear weapons in the nation's smaller 21st-century stockpile remain safe, reliable, and secure.

In 1995, the million-fold improvement was thought by many to be unattainable. Fulfilling the goal required the development of computers that could perform 100 trillion operations per second (teraops) together with data management and simulation tools that could run efficiently on highly parallel computers. At the October ASC ceremony, visitors had a chance to see two machines developed by IBM for the ASC program: the 100-teraop ASC Purple and the revolutionary BlueGene/L, which is the world's fastest supercomputer at 280 teraops. Now routine at Livermore, terascale computing is contributing to stockpile stewardship and is also leading to scientific discoveries in other fields, including materials sciences, astrophysics, climate science, environmental and energy science, and biophysics. Exciting progress in these areas appears throughout this report.

Long-term success in stockpile stewardship depends on much more than these remarkable advances in computing—greatly improved experimental capabilities, such as the National Ignition Facility (NIF), are also essential. A breakthrough capability, NIF is the only facility able to create, in a laboratory setting, the conditions necessary to experimentally study physical processes that occur during the nuclear phase of an exploding nuclear weapon. Major progress continues to be made on completing NIF construction and preparing for fusion ignition experiments with the 192-beam laser in less than five years. Together, vastly improved simulations and experimental capabilities are providing the nation with the tools required to better assess weapon performance, resolve issues, and refurbish weapons or provide reliable replacements.

Secretary of Energy Samuel W. Bodman visits Livermore.

Materials simulations win prestigious Gordon Bell Prize.

World's fastest supercomputers.

Record-setting laser energy at the National Ignition Facility.

Mission-directed, multidisciplinary science and technology at Livermore is also focused on reducing the threat posed by the proliferation of weapons of mass destruction as well as their acquisition and use by terrorists. For this vital and growing facet of the Laboratory's national security mission, we are developing advanced technologies, such as a device to detect highly enriched uranium inside cargo containers. This technology made *Discovery* magazine's list of "top 100 stories" in 2005. Another Livermore-developed radiation detector and a bioagent monitor each won an R&D 100 Award for top technological advances in 2005. The Laboratory also provides unique expertise, integrating analyses, and operational support to the Department of Homeland Security. The National Atmospheric Release Advisory Center (NARAC) performs real-time assessments of the atmospheric dispersion of hazardous materials, and the Biodefense Knowledge Center, a multilaboratory collaboration, offers expertise and in-depth analyses of biodefense issues.

Emerging threats to national global security are broader than defense and homeland security. Livermore pursues major scientific and technical advances to meet the need for environmental quality, clean energy, better water management, and improved human health. Our *2005 Annual Report* highlights scientific explorations in scales ranging from nanotubes and picoseconds to the Earth's biosphere and centuries. Research at the Laboratory is often pursued for multiple purposes and sponsors, such as radiation detection technologies for both national security and astrophysics, and bioscience for biosecurity and better human health. Breakthroughs often have many applications, and the cross fertilization of programs with new ideas keeps

Tropical temperature data reconciled with climate simulation models.

Secretary of Homeland Security Michael Chertoff at the Laboratory.

Detectors for homeland security win R&D 100 awards.

Large Synoptic Survey Telescope development.

Livermore intellectually vital and an exciting place to work.

The Laboratory's national security mission means that employees shoulder extraordinary responsibilities to work safely and securely, and the Laboratory must be protected against evolving threats. Safety and security are the most important considerations in day-to-day operations, and they are integrated into all programmatic work planning and execution. We are striving to adapt and follow best business, safety, and security practices, and we work to continually improve all aspects of Laboratory operations. Quality operations and scientific and technical excellence together make possible Livermore's programmatic accomplishments and sustain public trust in the Laboratory.

Exceptional people make Livermore an exceptional national laboratory. An outstanding, dedicated staff is the key to our successes. One of my top priorities is workforce management—making sure that we recruit a talented, diverse staff and offer career growth opportunities for everyone. I want to ensure that Livermore continues to offer employees an opportunity to accomplish something important for the country, access to outstanding research capabilities and facilities, and an inclusive, collegial work environment.

Our priorities remain clear. We must continue our strong programmatic and mission focus; keep the Laboratory operating smoothly using best business, safety, and security practices; meet our compliance commitments; and meet customer expectations.

Finally, I would like to add a word of thanks on behalf of everyone at the Laboratory to one of Livermore's exceptional employees: Michael Anastasio. We congratulate him on becoming the next director of Los Alamos National Laboratory, we wish him continuing success, and we thank him for his outstanding leadership of Lawrence Livermore through 2005.

Magazine covers feature Laboratory science.

Outreach activities highlight World Year of Physics.

The National Institutes of Health extend cancer research partnership with UC Davis.

Successful clean-up of an unused nuclear facility.

Nuclear Weapons Stockpile Stewardship

Lawrence Livermore National Laboratory was established in 1952 to help ensure national security through the design, development, and stewardship of nuclear weapons. National security continues to be the Laboratory's defining responsibility. Livermore is one of the three national security laboratories that support the National Nuclear Security Administration (NNSA) within the Department of Energy (DOE).

Livermore plays a prominent role in NNSA's Stockpile Stewardship Program for maintaining the safety, security, and reliability of the nation's nuclear weapons. The Stockpile Stewardship Program integrates the activities of the U.S. nuclear weapons complex, which includes Livermore, Los Alamos, and Sandia national laboratories as well as production sites and the Nevada Test Site. As the nuclear weapons in the stockpile continue to age, Laboratory scientists and engineers are challenged to ensure the weapons' performance and, as necessary, refurbish them or provide reliable replacements without conducting nuclear tests.

Working with the other NNSA laboratories, Livermore is attending to the immediate needs of the stockpile through assessments and actions based on a combination of laboratory experiments and computer simulations of nuclear weapon performance. In addition, the Laboratory is acquiring more powerful experimental and computational tools to address the challenging issues that will arise as the nation's nuclear weapons grow older. These vastly improved scientific capabilities will contribute to NNSA's goal of transforming the nuclear weapons complex, making it more responsive to the need for a smaller 21st century stockpile that is even safer, more secure, and easier to maintain.

Annual Assessment of the Stockpile

Livermore is a key participant in formal review processes and assessments of weapon safety, security, and reliability. In 2005, the Laboratory met all milestones in support of the tenth cycle of the Annual Assessment Review. First mandated by the President in 1995, this annual review of the stockpile is now required by law. The review assesses the current status of the stockpile and provides the President an informed judgment of whether a resumption of underground nuclear testing is warranted to resolve any issues about the reliability or safety of weapons. The formal process is based on technical evaluations made by three national laboratories and on advice from the secretaries of Energy and Defense, the three laboratory directors, and the commander-in-chief of Strategic Command.

Secretary of Energy Samuel W. Bodman, who signs the Annual Certification letter to the President, visited the Laboratory in August to learn more about programs and talk to employees.

Lawrence Livermore and Sandia prepare Annual Assessment Reports for each of the nuclear weapons systems for which the two laboratories are jointly responsible: the W62 and W87 intercontinental ballistic missile (ICBM) warheads, the B83 strategic bomb, and the W80 and W84 cruise missile warheads. As input to the reports, Laboratory scientists and engineers collect, review, and integrate all available information about each weapon system, including physics, engineering, chemistry, and materials science data. This work is subjected to rigorous, in-depth intralaboratory review and to expert external review, including formal use of red teams. Weapons experts from Livermore also provide peer review for the Annual Assessment Reports prepared by Los Alamos and Sandia for the weapon systems under their joint responsibility.

Quantifying Uncertainties in Performance

For the Annual Assessment Review, formal certification of refurbished warheads, and resolution of issues arising about deployed systems, Laboratory scientists and engineers depend on an extensive range of aboveground testing, vastly improved simulation capabilities, and the existing nuclear test database. This information is essential input into a methodology called quantification of margins and uncertainties (QMU), developed by Livermore and Los Alamos. QMU serves as a formal framework to underpin evaluations of weapons performance and technical decisions about refurbishing weapons or providing reliable replacements. The methodology, which entails the development and application of a rigorous set of quantitative standards, is analogous to the use of engineering safety factors in designing and building a bridge. For every functional requirement, the performance margin is quantified (i.e., how far is the system performance from failure) and compared to the uncertainty in the estimate of that margin (i.e., how uncertain are the estimates of performance and the point of failure).

QMU is being strengthened by research directed at reducing key uncertainties, and in one important area of weapons performance, scientists made a significant breakthrough in 2005. Laboratory researchers proposed a resolution to the energy balance issue, a 40-year-old anomaly in nuclear test data that previously could not be explained. Because of the anomaly, an ad hoc calibration had to be added to computer simulations of specific weapon systems to match the results of underground tests. Until now, the search for a physics-based model to replace the calibration had failed due to the complexity of the physics and limited computational and experimental capabilities. Based on results from recent high-fidelity, non-nuclear experiments, the availability of superior simulation tools, and careful re-examination of archival nuclear test data, Laboratory scientists developed a consistent, science-based explanation for the anomaly. Future experiments at the National Ignition Facility (NIF) will serve to confirm the work. A self-consistent physics foundation for explaining energy balance is now part of the QMU methodology. The result is reduced uncertainties when evaluating the performance of stockpiled weapons, life-extension modifications, and options for reliable replacement warheads.

As Livermore and Los Alamos continue to refine QMU, the methodology is being widely implemented in warhead assessment activities. The QMU approach was first applied in Livermore's certification of the design changes to refurbish and extend the life of the W87 ICBM warhead. Today, the methodology serves as the basis for Livermore's certification plans for extending the life of the W80 warhead (see below). In addition, QMU is supporting Livermore's activities for the Reliable Replacement Warhead feasibility study and peer review of Los Alamos' work on the W76 and W88 submarine launched ballistic missile (SLBM) warheads.

Life Extension of the W80 Cruise Missile Warhead

The Laboratory is on schedule in meeting key (Level Two) milestones in the W80 Life Extension Program (LEP). NNSA and the Air Force are pursuing the LEP to refurbish W80 cruise missile warheads, which first entered the stockpile in 1981. The refurbishment work will be carried out at NNSA production facilities based on engineering designs developed and certified by Lawrence Livermore and Sandia-California national laboratories. The program has moved from Phase 6.3 (engineering development) to Phase 6.4 (production engineering) after successful completion of two major reviews. The first review was the Phase 6.3 to 6.4 Interlaboratory Peer Review conducted by Los Alamos. Second, in early fiscal year 2005, the Department of Defense completed its Preliminary Design Review and Acceptance Group Review. Production preparations are ongoing, with numerous engineering releases sent to the production plants to support First Production Unit dates for components.

An extensive program of experimental and computational activities is under way to support the W80 LEP, executed according to the QMU approach. Laboratory scientists and engineers have performed high-resolution, two- and three-dimensional computer simulations to design and test new components, predict system performance, and prepare for certifying proposed modifications to the weapon. The simulations have also assisted in the preparation of experiments, which, in turn, provide data to compare with model predictions. All planned engineering-development experiments to validate and improve models for the modified W80 design (the W80-3) were completed in 2005. These included integrated (large-scale) hydrodynamics experiments, focused (smaller-scale) hydrodynamic tests, and relevant high-energy-density physics experiments at the University of Rochester's OMEGA laser. As production activities progress and mature, a new phase of qualification experiments will begin. They will demonstrate that the hardware from the production facilities performs as designed.

Technicians attach instrumentation to the exterior of a W80 Environmental Test Unit.

W80 Environmental Test Unit installed in an Advanced Cruise Missile in preparation for flight test FTU-1, flown in September.

Hydrodynamic tests, such as the ones performed as part of the W80 LEP, are a particularly important part of the Stockpile Stewardship Program. In some of the large-scale tests—called Integrated Weapons Experiments—scientists study the performance of mock weapon primaries as their pits are imploded by high explosives. Smaller-scale Focused Experiments, performed to study specific physics or engineering issues, are also an essential feature of the Stockpile Stewardship Program. Altogether, Livermore fired 7 Integrated Weapons Experiments and 45 Focused Experiments for the weapons program in 2005. Over the past two years, the cost effectiveness of hydrodynamics testing for the weapons program has increased by more than 100 percent as measured by the number of tests per dollar. This increased productivity resulted from an improved approach to planning and executing hydrodynamic tests. The goals were to maximize return-on-investment in the data gathered and continually improve testing, based on feedback from experimental teams.

Livermore, Sandia, and the Air Force also are performing flight tests for the W80-3. Excellent quality data were obtained in all five captive-carry flight tests, flown between February 2003 and July 2005. Captive-carry experiments mount an instrumented W80 test warhead into either an Air Launched Cruise Missile (ALCM) or an Advanced Cruise Missile (ACM) and then fly an extended B-52 mission to measure all aspects of the thermal and structural flight environment envelopes. The first free-flight test of the W80-3 was flown in September 2005 on an ACM. This test confirmed key design input requirements, such as the ejection shock level when the cruise missile is explosively separated from the B-52 bomber.

With flight and ground environment data measured, a major development ground test with the latest W80-3 hardware, called the Full System Engineering Test (FSET), began in late 2005. The flight program information provided much of the required thermal and mechanical shock and vibration conditions that FSET uses to qualify the new W80-3 warhead design. These extensive tests take over a year to complete, and they provide confidence in the future certification of the W80-3.

Dedicating Two of the World's Fastest Supercomputers

The Laboratory celebrated the tenth anniversary of NNSA's Accelerated Strategic Computing Initiative with a ceremony in October. Speakers included Ambassador Linton Brooks, NNSA administrator; Ray Orbach, director of the DOE Office of Science; and Nicholas Donofrio, IBM executive vice president for innovation and technology. Now known as the Advanced Simulation and Computing (ASC)

Program, this ambitious effort was launched in 1995 to achieve a million-fold increase in computing capability. The goal was a supercomputer that could operate at 100 trillion operations per second (100 teraops), estimated to be the minimum capability for modeling the full performance of a nuclear weapon in three dimensions with sufficient resolution. Dedication of the 100-teraops ASC Purple and the even faster BlueGene/L machines at the ceremony marked the outstanding success of ASC. NNSA and DOE are strongly committed to continuing to push the frontiers of high-performance scientific computing in partnership with U.S. industry. Both ASC Purple and BlueGene/L reside in the newly constructed Terascale Simulation Facility (see p. 36).

The ASC Purple computer system was delivered from IBM, installed, and tested in 2005. With more than 12,000 next-generation IBM Power5 microprocessors, 2 million gigabytes of storage, and 17,000 cables totaling 140 miles, ASC Purple is an enormous machine with the computing capacity of 25,000 high-end personal computers. Operation of the computer and cooling system requires 7.5 megawatts of electric power, equivalent to the usage of about 7,500 average homes. In spring 2006, the classified Purple system (1,423 nodes and 93.4 teraops) will first become available for production runs of classified problems, which can take weeks to complete. Purple will be used to run the most demanding three-dimensional weapons simulation codes with high-fidelity physics models. The unclassified uPurple system (109 nodes, 6.6 teraops) will become available at the same time for unclassified science runs.

Sitting at the number-one spot on the Top500 List of the world's fastest supercomputers is BlueGene/L. With delivery from IBM of the final 32 of 64 racks in summer 2005, BlueGene/L clocked an astonishing 280.6 teraops on the industry-standard LINPACK benchmark. Each rack is a single air-cooled cabinet with 1,024 nodes (2,048 processors). With its 65,536 nodes and system-on-a-chip technology, BlueGene/L is a world apart from other scalable computers not only in terms of performance but also in size, cost, and design. Livermore computer scientists and collaborators successfully integrated the machine into the Laboratory's computer infrastructure during the year. The endeavor entailed developing software for the control system, resource manager, job scheduler, debugger, and parallel file system. Running scientific problems in the first half of the year helped the system integration effort by revealing issues that had to be resolved. These runs also produced first-time results on important molecular dynamics problems.

One breakthrough three-dimensional molecular dynamics calculation performed on BlueGene/L won the 2005 Gordon Bell Prize, which is awarded to innovators who advance high-performance computing. A Livermore-IBM team of scientists ran a newly developed three-dimensional molecular dynamics code at a sustained speed of about 100 teraops to study the solidification of tantalum and uranium. In the 2-million-atom simulation, molten tantalum at 500 kelvins was compressed, and scientists examined the process of solidification, from nucleation to growth to grain-size structures. The 30-hour

NNSA administrator Linton Brooks, then-Laboratory director Michael Anastasio, IBM executive vice president Nicholas Donofrio, and DOE Office of Science director Ray Orbach (right to left) attend ceremonies to mark the tenth anniversary of the Accelerated Strategic Computing Initiative.

Breakthrough materials science simulations won the prestigious Gordon Bell Prize.

computer run simulated about 0.75 nanosecond—long enough to study the physics. The behavior of metals under high pressures and temperatures is an important issue for stockpile stewardship. Several other finalists for the prestigious Gordon Bell Prize entered work also performed on BlueGene/L.

Understanding Plutonium

Plutonium is an extremely complex material, critically important to the functioning of weapons. One of the major scientific challenges of the Stockpile Stewardship Program is comprehending the detailed properties of plutonium metal and alloys and how they age. Experiments at the Joint Actinide Shock Physics Experimental Research (JASPER) Facility and with diamond anvil cells are helping scientists better quantify properties of this material. Located at the Nevada Test Site, JASPER is a 30-meter-long, two-stage gas gun that accelerates a projectile to speeds of up to 8 kilometers per second.

In a JASPER experiment, the impact of the projectile produces an extremely high-pressure shock wave (about 600 gigapascals or 6 million atmospheres) in the targeted material, raising its temperature to as high as 7,000 kelvins. Through precise measurements of shock velocity, scientists are improving plutonium equation-of-state models used in weapon performance calculations. Although fewer tests were performed at JASPER than during the previous fiscal year, all experiments produced excellent data and several broke new ground. For example, researchers acquired the first simultaneous dynamic comparison data for aged versus unaged plutonium.

Laboratory experiments using diamond anvil cells complement shock physics experiments. A diamond anvil cell is a small mechanical press that squeezes a microgram of material between two small, flat-tipped diamonds, achieving pressures as high as 100 gigapascals. In diamond anvil experiments fielded at the Advanced Photon Source at Argonne National Laboratory and other synchrotron light sources, Livermore scientists obtained high-accuracy equation-of-state data for plutonium samples whose ages ranged from 0 to 45 years. Experimental data also characterized differences in equations of state among plutonium alloys and validated equation-of-state and phase-transition models.

Major Progress at the National Ignition Facility

Major progress continues to be made on the NIF project and preparing for fusion ignition experiments with the 192-beam laser. The NIF project is meeting all of its technical performance, cost, and schedule milestones. Current plans are to begin the first ignition experiments in fiscal year 2010. NIF's laser beams will compress fusion targets to the conditions required for thermonuclear burn, liberating more energy than is required to initiate the fusion reaction. Inertial confinement fusion energy is a long-standing program goal within DOE. NIF will offer researchers the capability to study physical processes at

The target chamber at the JASPER facility is specially designed to ensure that plutonium dust or fragments are not released into the environment after an experiment.

temperatures approaching 100 million degrees and 10 billion atmospheres, conditions that exist naturally only in the interior of stars and planets and in exploding nuclear weapons.

NIF is vital to the success of the Stockpile Stewardship Program. It is the only facility capable of creating, in the laboratory, the conditions necessary to experimentally study physical processes that occur during the nuclear phase of an exploding nuclear weapons. Data from precisely diagnosed experiments will elucidate key weapons performance issues and assist in validating physics models and numerical simulation codes. Over the coming decades, NIF experiments will also help train and rigorously test the capabilities of weapons scientists, on whom the nation depends to assess the safety, security, and performance of the U.S. stockpile.

In August 2005, two shots using eight laser beams achieved a record-setting 152 kilojoules of energy. With just its second "quad" of 192 beams commissioned, NIF produces more energy than the 60-beam OMEGA laser at the Laboratory for Laser Energetics at the University of Rochester, the next largest system. The combined output from the eight beams, referred to as a bundle, surpassed the Main Laser Operational Qualification goal of 125 kilojoules of infrared light per bundle. Beam quality, as well as total energy, exceeded design specifications. Before these shots took place, a newly designed automated computer shot control software dubbed HOTShots, or Hands Off Target Shots, began controlling all NIF shots.

The NIF project met another milestone in October with the installation of the 1,000th line replaceable unit (LRU). Weighing between 500 and 1,000 kilograms each, LRUs are complex modules containing instrumentation and optical components to amplify laser light as it passes through. There are over 20 different types of these precision electro-optical/mechanical structures. When completed, NIF will have more than 6,200 LRUs. Because

Workers are dwarfed by the final optics assemblies entering the 10-meter-diameter target chamber (top) at the National Ignition Facility (above).

modular LRUs can easily be removed and refurbished or upgraded, NIF will have less downtime and be easier to maintain over the long term. The LRUs are assembled and tested in the Optics Assembly Building, a cleanroom facility adjacent to NIF. The optical surfaces of LRU components need to be aligned to within a fraction of a millimeter. After technicians validate an LRU's alignment, cleanliness, and operation, the LRU is moved in a robotic portable cleanroom to one of the laser bays and inserted into a beamline.

NIF Looks Toward Ignition

The results of a series of four-beam NIF experiments, published in *Physical Review Letters*, indicate that NIF is on the right path to successfully achieving ignition. The experiments studied plasma conditions inside hohlraums, small cylinders that convert laser light to x rays. In future fusion experiments, x rays will cause the implosion of a tiny capsule inside the hohlraum to create fusion ignition. The four-beam experiments examined the hohlraum's radiation temperature and how rapidly plasma is produced. These data are important because laser energy delivered late in a long pulse (more than several nanoseconds) is ineffective for achieving ignition if the hohlraum is already filled with plasma.

Advanced diagnostics measured the x-ray spectra and radiation temperatures inside the hohlraum in experiments using various sizes of hohlraums and different laser pulse lengths. Instruments also imaged the x rays that were energetic enough to escape the hohlraum. The precise data gathered were then compared to the predictions of theoretical and detailed computational models, which proved to be remarkably accurate. These important findings confirm that the larger hohlraums to be used for NIF ignition experiments should create plasma slowly

NIF's 1,000th line-replacable optical unit is maneuvered into position.

enough to achieve the implosion conditions necessary for ignition.

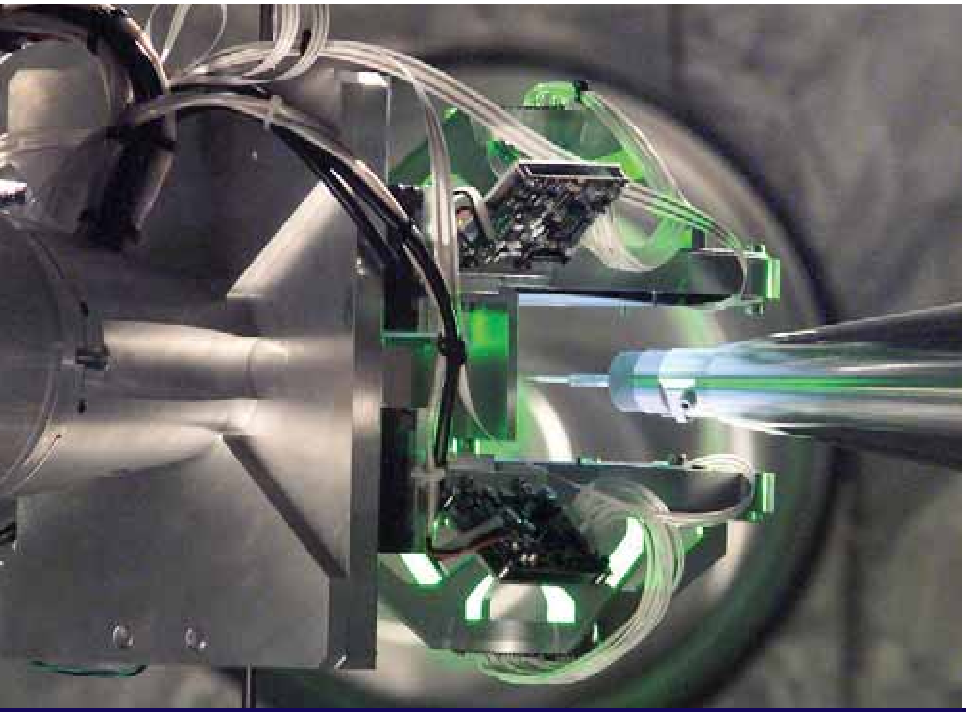
Planning for future ignition experiments at NIF is under way. Two workshops were held at Livermore in January and February 2005 to develop an integrated plan for achieving ignition and coordinating activities and responsibilities. Representatives from all laboratories participating in the ignition campaign attended the workshops. The resultant *National Ignition Campaign Execution Plan* was approved by NNSA in June. As mentioned, the plan calls for the first ignition experiments in fiscal year 2010. Ongoing experiments at OMEGA and other facilities are testing diagnostic concepts planned for NIF as well as alternative ideas for ignition target designs. At Livermore, good progress was made last year in the areas of target design, target fabrication, and advanced diagnostic development.

Planning for the Future

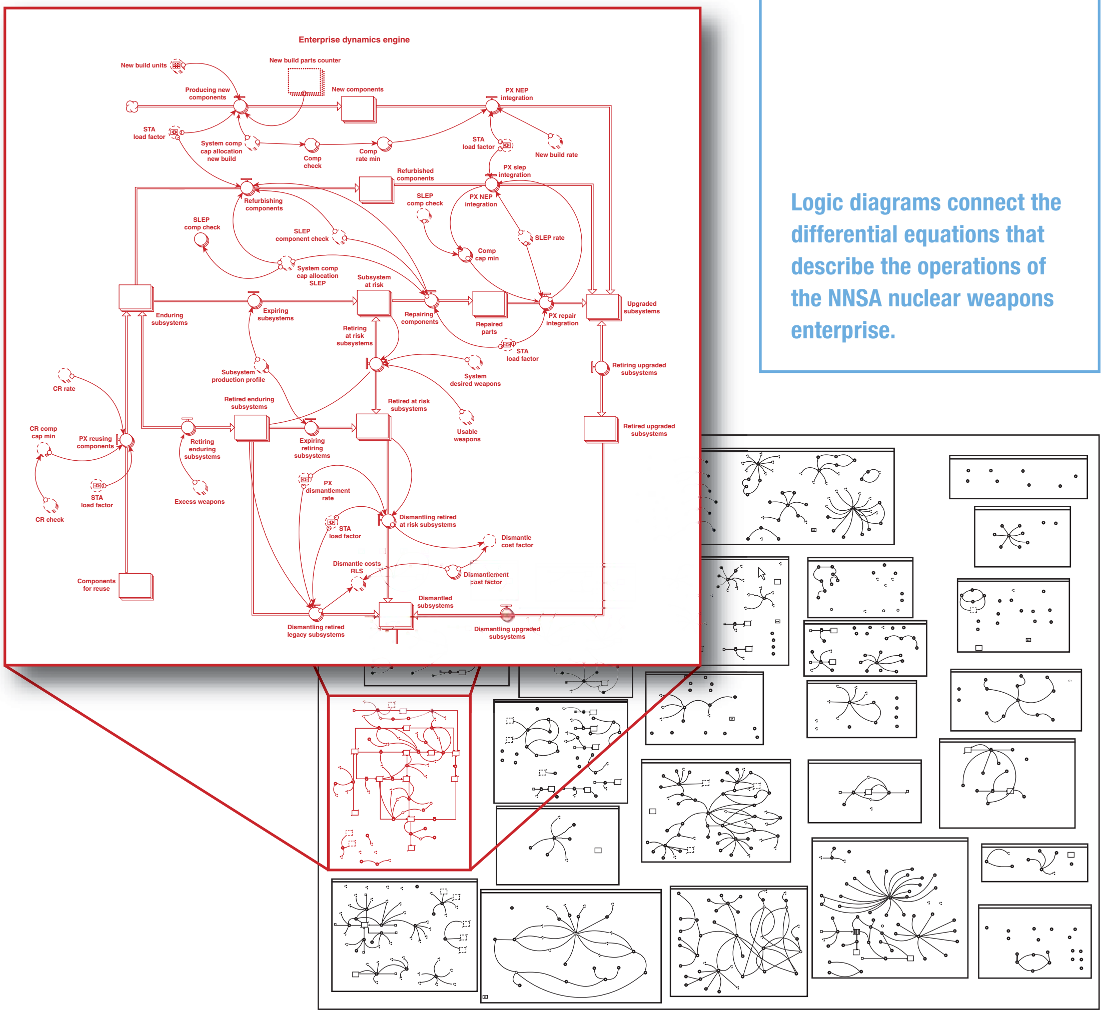
As the nation adapts to the security threats of the 21st century, the role of nuclear weapons is changing, and so must the large nuclear weapons complex, or enterprise. The nation is committed to maintaining a reliable, safe, and secure nuclear deterrent with the lowest possible number of weapons. However, NNSA's nuclear weapons enterprise has many large and aging facilities, and it must support legacy warhead designs well beyond their originally projected lifetimes. A series of top-level studies and reviews at DOE, NNSA, and the Department of Defense (DoD) has called for a smaller, more agile nuclear enterprise. It needs to be more cost efficient and able to respond quickly to sudden surprises, such as a major geopolitical change or the discovery of an acute technical problem in the nuclear stockpile.

The NNSA faces the challenge of making the transition to a smaller, more agile enterprise while also maintaining an aging stockpile. To help meet this challenge, a team of Livermore researchers has built a modeling tool for testing future enterprise strategies. The team combined differential equations with an enormous database of information to model in extreme detail how each facility in the enterprise functions. This detail is required because the NNSA enterprise is a highly nonlinear system; activities among the plants and laboratories are complicated and interdependent. Rigorous verification and validation serve to ensure that the new model appropriately reflects the workings of the enterprise.

The Livermore model represents the enterprise's flow of activities by incorporating accurate financial, production, warhead dismantlement, and stockpile data. The goal is for NNSA managers to see more clearly how policy decisions might affect the enterprise. They could then optimize the transition from the present infrastructure to a more responsive one while maintaining important stockpile commitments. The model has received high marks for thoroughness and utility from managers at DOE, NNSA, and many NNSA facilities. U.S. Strategic



Inside the target chamber, an alignment system is used to position a NIF target, which would be at the tip of the target positioning system entering from the right.



Logic diagrams connect the differential equations that describe the operations of the NNSA nuclear weapons enterprise.

Command and the Defense Threat Reduction Agency are collaborating with Livermore experts to develop a complementary model of the DoD's nuclear enterprise.

NNSA managers are considering a long-term approach for a sustainable nuclear weapons enterprise that would shift from a program of warhead refurbishment to one of warhead replacement. To better evaluate this proposal, NNSA began the Reliable Replacement Warhead (RRW) Program with support from Congress, and Livermore is an active participant. The program's goal is to determine the effectiveness of replacing existing warheads with ones manufactured from materials that are more readily available and more environmentally benign than those used in current designs. These modified warheads would be much less costly to manufacture, their designs would include advanced safety technology, and their safety and reliability would be easier to certify. Establishing a responsive nuclear infrastructure, together with the RRW Program, would make possible additional stockpile reductions.

Threat Reduction and Homeland Security

Security at home and across the globe requires a reduction in the threat posed by the proliferation of weapons of mass destruction (WMD) as well as their acquisition and use by terrorists. Lawrence Livermore provides technologies, analysis, expertise, and operational capabilities to preclude WMD proliferation or terrorist attack.

A distinguishing feature of Livermore's work for this enduring and compelling mission is its integrated, end-to-end approach. The full spectrum of threats is addressed—from preventing proliferation at its source, to detecting proliferant activities and identifying ways to counter those efforts, to responding to the threatened or actual use of WMD. Because terrorists and other adversaries could use any type of weapon, the United States must counter and defend against all threats: biological, chemical, and nuclear. Systems and technologies for use at home and abroad are required to forestall, interdict, and defuse WMD threats as far from their targets as possible.

The Laboratory draws on more than 50 years of experience in all aspects of nuclear weapons as well as extensive resources in biology, chemistry, engineering, and computations to tackle the challenges of WMD proliferation and terrorism. Livermore researchers are also developing tools and technologies to meet current Department of Defense needs and to assist in the broader defense transformation effort.

Preventing Proliferation at the Source

Lawrence Livermore participates in a suite of international cooperative activities aimed at preventing proliferation by securing nuclear materials at the source. Foremost among these efforts is the National Nuclear Security Administration's Material Protection, Control, and Accounting (MPC&A) Program, which is helping Russia enhance the security of vast quantities of Soviet-legacy weapons-usable nuclear material. Livermore is one of only four U.S. laboratories authorized to work with the Russian Ministry of Defense.

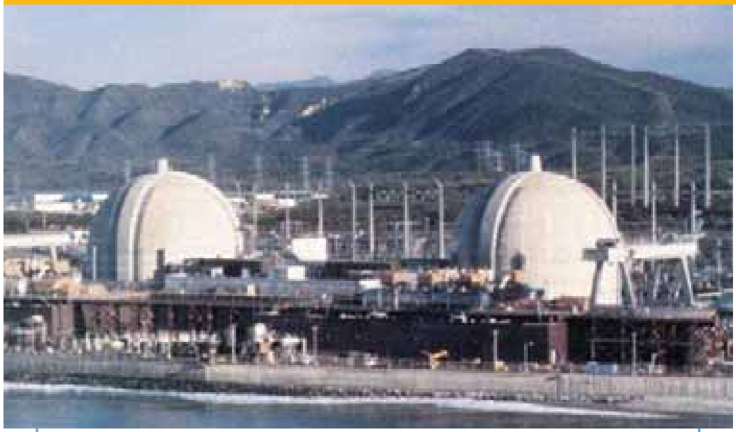
In 2005, the Laboratory completed comprehensive upgrades at the third of four naval nuclear weapons storage sites. In addition, the Kola Technical and Training Center was opened in July to support sustainable MPC&A for the Russian Navy nuclear sites, with courses in physical protection, protective forces, and MPC&A management. Work to maintain previously upgraded Russian Navy sites continued, as did the development of MPC&A regulations for the Russian military. Projects within the civilian Rosatom sector also continue on schedule. These include activities at various sites and the Federal Information System effort, which Livermore leads, to establish a comprehensive national nuclear material accounting system for Russia.

Livermore also participates in the Global Radiological Threat Reduction Program, which aims to keep radiological materials out of the hands of terrorists. Laboratory scientists are working with the Russian Ministry of Defense to remove and secure storage of radioisotopic thermoelectric generators in the Russian Far East. These devices, which contain large-curie quantities of strontium-90 and are used to power various operations in remote locations, will be replaced with power sources—such as solar—that are not attractive to terrorists. Other activities to secure at-risk radiological materials in Albania, Tanzania, and Kenya are nearing completion.

Strengthening International Safeguards

Laboratory scientists have developed a new technology—scintillator-based antineutrino detection—to enhance international nuclear safeguards. This detection methodology provides a

Aid to the Russians in securing their weapons-grade nuclear material included opening the Kola Technical and Training Center in Murmansk (left) and upgrading security at naval nuclear weapons storage sites.



A new radiation detection technology that measures a reactor's antineutrino emissions was tested at the San Onofre Nuclear Generating Station.

Livermore scientists helped to install the first seismic measuring stations in the United Arab Emirates.

non-intrusive, near-real-time way to monitor for unauthorized plutonium production. Using a 0.64-ton antineutrino detector located a few tens of meters from the core of a commercial power reactor in Southern California, the research team demonstrated experimentally the ability to track power, fuel burnup, and plutonium content using the antineutrino signal. These measurements are taken at the earliest point in the fuel cycle at which plutonium content can be assessed, namely the moment of production.

The detector measures about two meters on a side; the goal is to reduce its size to about one meter on a side with no cryogenics or other complicated "life support" systems. The result will be a readily deployable and movable system. The International Atomic Energy Agency has expressed interest in antineutrino detectors to ensure that nuclear fuel in civilian power reactors is not diverted for weapons purposes.

Engaging Scientists Worldwide to Prevent Proliferation

Laboratory researchers participate in Global Initiatives for Proliferation Prevention, which strives to create sustainable jobs for former Soviet weapons scientists and engineers in the high-tech commercial marketplace. In one such project, the Laboratory is working with the Lebedev Physical Institute and Valley Forge Composites Technology, Inc., on an accelerator-based device to detect hidden explosives in luggage and cargo. The explosives-detection system is based on a small-scale electron accelerator developed by Lebedev. The potential market for this technology is huge; the U.S. market demand alone is approximately $2 billion per year for hardware and $2.5 billion for maintenance and support services.

The Laboratory is also involved in a variety of activities to engage scientists and engineers in regions of the world where WMD proliferation is a concern. Scientific collaboration on issues of regional interest helps to promote understanding and cooperation and defuse tensions. For example, Lawrence Livermore and the United Arab Emirates (UAE) University organized the Gulf Seismic Forum 2005, held in Al Ain, which brought together scientists and engineers from Saudi Arabia, Yemen, Oman, UAE, Kuwait, Iran, Iraq, Jordan, Egypt, and Turkey. The forum laid the groundwork for establishing a regional data-sharing network to mitigate the effects of such natural disasters as earthquakes and foster cooperation in data sharing, analysis, and interpretation.

Advanced Nuclear-Threat Detectors

In January 2005, *Discover* magazine named its "top 100 stories," including a technology being developed by the Laboratory to counter the threat of nuclear or radiological terrorism. The device can detect highly enriched uranium inside cargo containers through active interrogation using a 14-MeV neutron source. In 2005, a new neutron source was installed, which led to a breakthrough in eliminating interference from oxygen activation. Now the highly enriched uranium signal stands out clearly, five to ten times above background signals.

Livermore scientists are enhancing gamma-ray imaging technologies to detect small quantities of hidden nuclear material or locate nuclear material at a distance. One such technology is a large-area (0.6-m^2), scintillator-based, coded-aperture gamma-ray imager. This instrument provides real-time measurement of the radiation background and is ten times more sensitive than a non-imaging system of the same size. The imager, mounted inside a medium-size cargo truck moving at 16 kilometers per hour, was able to detect a one-millicurie cesium-137 source 83 meters away. The source was not detected when the instrument was in its non-imaging mode.

Versions of Livermore's Adaptable Radiation Area Monitor (ARAM) have been demonstrated in such challenging venues as the Defense Threat Reduction Agency Unconventional Nuclear Warfare Defense Program, the Department of Homeland Security (DHS) Countermeasures Testbed, a large FedEx package-handling facility, and various law enforcement agencies. The technology for this rugged, autonomous detection system has been licensed to a commercial partner. In 2005, *R&D Magazine* honored ARAM developers with an R&D 100 Award (see p. 49).

Deterring Nuclear Terrorism

A key deterrent to nuclear terrorism is the ability to identify the origin of interdicted nuclear materials or terrorist nuclear devices, information that offers clues to the identity of the perpetrators. An outgrowth of nuclear test activities in the 1980s, nuclear forensics work at the Laboratory makes use of an array of

The sensitivity of the large-area, scintillator-based gamma-ray imaging detector makes it able to detect very small quantities of nuclear material.

The Adaptable Radiation Area Monitor, which won an R&D 100 Award, has been commercialized and is in use at California borders.

Nuclear forensics can track illicit nuclear material back to its source. Recovered uranium oxide materials (left) are analyzed and compared to a collection of known uranium oxide samples.

equipment to develop physical, chemical, and isotopic profiles of a suspect sample down to the nanometer scale. Optical and scanning electron microscopy and other nondestructive techniques are first applied to determine the sample's overall composition and structure. Radiochemical and mass spectrometric analysis—including use of Livermore's newest secondary ion mass spectrometer, NanoSIMS—are the final steps to completely characterizing the sample.

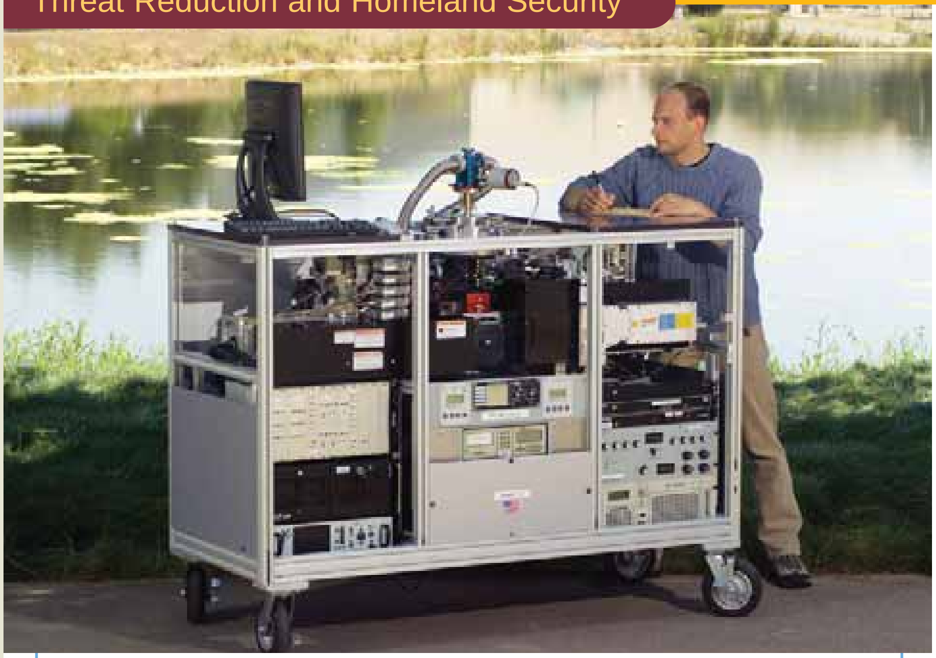
With funding from several sponsors, Livermore is extending its anti-nuclear terrorism activities on several fronts. Nuclear forensics will benefit from a revitalization of the Laboratory's base of expertise in radiochemistry. Researchers are extending models to better understand the effects of weapons in urban scenarios. In addition, operational procedures are being developed for collecting forensic evidence in the event of an actual nuclear terrorist incident.

Defending Against Biological Terrorism

Lawrence Livermore is one of the nation's leaders in the fight against biological terrorism and a major participant in the DHS multilaboratory Chemical and Biological Countermeasures Program. Laboratory scientists provide technical support to BioWatch, the national system for detecting a large-scale bioattack against key U.S. cities. Livermore is furnishing reachback expertise by on-call subject matter experts as well as capabilities in supplementary sample analysis and consequence management.

The Laboratory is also developing several systems that offer improvements in autonomy and speed over BioWatch. For example, the Autonomous Pathogen Detection System (APDS) can operate for more than a week without human intervention in airports, subways, and other high-traffic venues. In 2005, multiple APDS units were deployed in a major urban area and successfully operated as a network to monitor for the airborne release of biological agents. To ensure that APDS meets real-world needs, it is being improved upon and demonstrated through extensive interactions with public health officials, facility operators, security and law enforcement agencies, and other stakeholders.

Deployment of the Autonomous Pathogen Detection System in subway stations demonstrated the system's ability to perform reliably without human intervention.



The Bioaerosol Mass Spectrometer, which won an R&D 100 Award, was connected to the air handling system in a major airport. The instrument demonstrated long-term, reliable performance.

Biorestoration after a terrorist attack could make use of L-Gel, a spray-on material for quickly and effectively destroying bioterror agents.

Another instrument under development at Livermore is the Bioaerosol Mass Spectrometer (BAMS). Unlike APDS and other assay-based instruments, BAMS does not require reagents. It uses a combination of laser-induced fluorescence and mass spectrometry to rapidly detect and differentiate a broad range of biothreat agents (e.g., bacterial spores, bacterial vegetative cells, viruses, and toxins). BAMS tests particle by particle in real time (under one minute) without any sample preparation. In 2005, as part of the DHS Enhanced Bioaerosol Detector Project, BAMS was connected to the air handling system of a major airport where it demonstrated its ability to operate autonomously at 95 percent availability for weeks at a stretch. BAMS also received a 2005 R&D 100 Award (see p. 49).

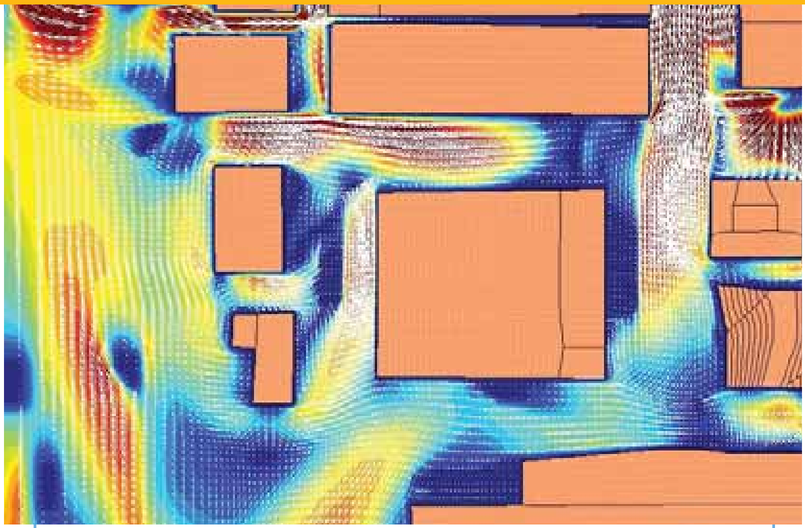
Technical Support for Anti-Bioterrorism

Livermore researchers are developing new diagnostics for key agricultural diseases. For example, under DHS's Bioassay and Signature Program and in partnership with the U.S. Department of Agriculture, the National Animal Health Laboratory Network, and the Plum Island Animal Disease Center, the Laboratory developed multiplexed assays for foot and mouth disease virus (FMDV) and endemic animal diseases that cause clinical signs that are indistinguishable from FMDV. In addition, in collaboration with the National Center for Foreign Animal Disease (Canada), Livermore developed a multiplexed protein-based test to differentiate animals infected with FMDV from those vaccinated against the disease.

Established by DHS at Livermore to provide in-depth analysis of biodefense issues, the Biodefense Knowledge Center (BKC) activated a 24/7 reachback capability in 2005 for all-WMD assessments under the new National S&T Threat Awareness and

Livermore has developed several diagnostics for animal diseases, including new assays for foot and mouth disease virus.

Department of Homeland Security Secretary Michael Chertoff (center) visited the Laboratory, including NARAC/IMAAC, in July.



NARAC/IMAAC models can accurately simulate building-scale flow and dispersion.

Reachback Program. The BKC prepared several detailed material threat assessments for biological, chemical, and radiological materials as well as rapid assessments on specific topics of concern. In May, the BKC deployed a state-of-the-art data-fusion architecture, developed by Laboratory researchers in the Information Operations and Analysis Center, that enables the integration of various static and real-time data feeds. The BKC also participated in three major exercises, including the TopOff-3 full-scale national counterterrorism response drill.

Under a three-year DHS Bio-Restoration Demonstration Project, Lawrence Livermore and Sandia researchers developed restoration plans to enable an airport hit with a bioterrorist attack to be quickly decontaminated and reopened while protecting human health and the environment. They devised improved, statistically based sampling methodologies that allow public health agencies to better characterize and understand the extent of contamination. The team developed a rapid viability test that can determine within a few hours (instead of days) whether pathogens are dead or alive, which will greatly shorten cleanup times. This project focused on San Francisco International Airport, but many of the concepts are applicable to other airports and other transportation systems, such as subways.

Emergency Planning and Response

Lawrence Livermore participates in numerous emergency response activities. In addition to providing critically needed local, regional, and national response capabilities, these efforts give Laboratory personnel first-hand experience in field operations, insight into the needs of emergency responders, and guidance to technology development efforts.

The National Atmospheric Release Advisory Center (NARAC), sited at and operated by Lawrence Livermore, is the premier capability in the U.S. for real-time assessments of the dispersion and potential impact of hazardous materials released into the atmosphere. NARAC models the behavior of radiological, chemical, biological, and natural (e.g., smoke) materials on global, regional, local, urban, and building scales. Since April 2004, NARAC has been the interim provider for the DHS-led Interagency Modeling and Atmospheric Assessment Center (IMAAC), which serves as the coordinating center and single source of federal plume modeling predictions in the event of a nationally significant incident.

In 2005, NARAC/IMAAC supported thousands of drills and exercises and 20 real-world events. As part of the research and development portfolio that keeps NARAC/IMAAC capabilities on the cutting edge, Livermore scientists have developed a method for reconstructing events that integrates observational data with predictive models to determine unknown source terms. In most real-world events, rapid characterization of the source of the

release (location, composition, and release rate) from limited information is critical to providing the timely and accurate predictions needed by decision makers.

The Laboratory is a key member of the DOE's nuclear emergency response programs that deal with the full range of nuclear incidents, from missing industrial sources to nuclear weapon accidents. These programs are more important than ever, given the clearly stated desire of various terrorist groups to acquire and use nuclear weapons or radiological dispersal devices. Livermore provides expert personnel for field and home teams, specialized equipment and technical capabilities for locating and identifying radiological materials and for diagnosing and disabling nuclear devices, as well as hands-on training for government agencies in nuclear incident response technologies and procedures.

Livermore maintains the highest level of expertise to respond to and train others to respond to nuclear incidents.

More than 140 Laboratory staff members were deployed to more than 25 events, including the major multiagency exercise Dingo King in August. Livermore also responded to nearly 60 requests for reachback analysis and assistance. More than 20 training sessions were held at Livermore in the use of advanced diagnostic instrumentation, technologies for disabling nuclear devices, and other incident response assets.

Armoring Gun Trucks in Iraq

With funding from the Defense Advanced Research Projects Agency and in collaboration with the U.S. Army, Livermore researchers developed gun truck armor kits that are now providing convoy protection for American troops in Iraq. The protection kits provide modular, easy-to-assemble armor that, with the addition of several machine guns, allows the military to convert five-ton supply trucks into gun trucks to protect convoys. The Laboratory developed the kits in response to a request by House Armed Services Committee Chairman Duncan Hunter (52nd District, California).

After Livermore built the first prototype truck, the technology was transferred to U.S. companies for production. To date, 71 armor kits are in service and another 45 are en route to Iraq and Afghanistan. Their effectiveness was dramatically demonstrated when a gun truck with the armor kit was struck by an improvised explosive device on March 23, 2005, near Fallujah, Iraq. All fourteen U.S. soldiers walked away unharmed.

Gun truck armor kits developed at Livermore are protecting American soldiers in Iraq.

Meeting Enduring National Needs

As part of its overarching national security mission, the Department of Energy (DOE) pursues research and development in areas of enduring importance to the nation. DOE mission priorities in energy and environment, bioscience, fundamental science, and advanced technologies are supported by Laboratory research programs. Livermore seeks challenges that reinforce its national security mission and have the potential for high-payoff results.

Long-term research is essential to providing the nation with abundant, reliable energy as well as a clean environment. Livermore's energy and environmental programs contribute to the scientific and technological basis for secure, sustainable, and clean energy resources for the United States and to reducing risks to the environment.

Bioscience research at Livermore enhances the nation's health and security. Projects in genetics, molecular biology, computational biology, biotechnology, and health-care research leverage the Laboratory's physical science, computing, and engineering capabilities. Research is directed at understanding the causes of ill health, developing biodefense capabilities, improving disease prevention, and lowering health-care costs.

Leadership in science and engineering is also vital to the nation's long-term security. Many projects, sponsored by the DOE's Office of Science and other customers, take advantage of the unique research capabilities and facilities at Livermore. Other work, supported by Laboratory Directed Research and Development funding, aims at breakthroughs to extend the Laboratory's capabilities in anticipation of new mission requirements.

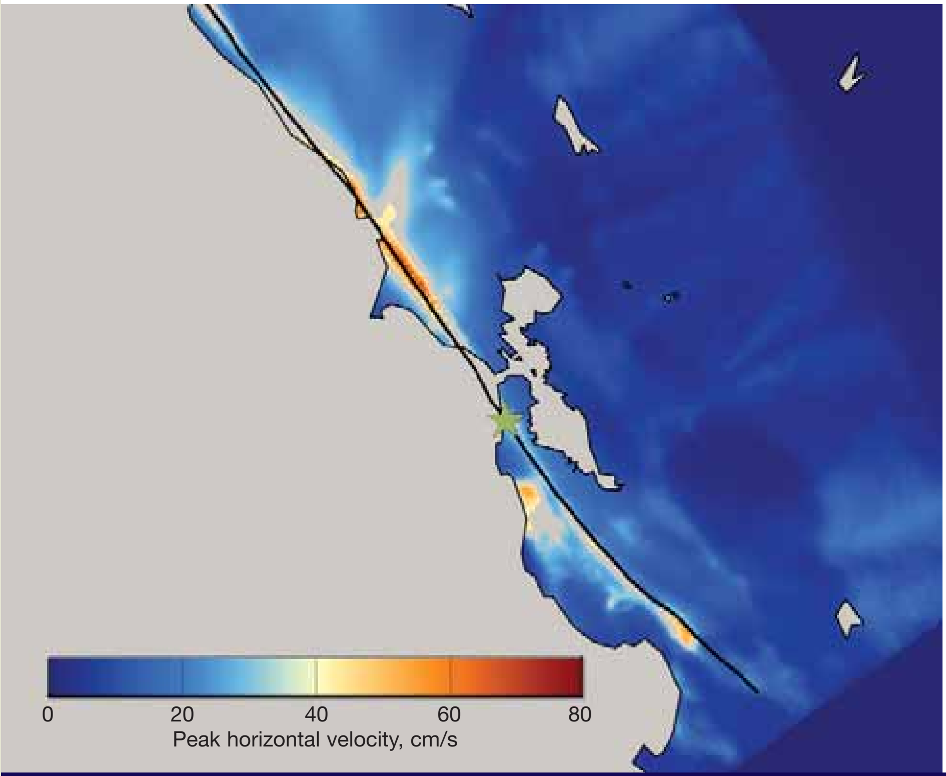
Scientific Discovery with Supercomputers

Ranked seventh on the Top500 List in June 2005, Livermore's Thunder supercomputer can process 23 trillion operations per second. It is available to Laboratory programs to run non-classified "grand challenge" problems—large calculations that promise breakthrough science. Since Thunder was installed in June 2004, researchers have used this Linux cluster for problems ranging in scale from high-resolution global and regional climate modeling to seismic simulations to protein folding and molecular dynamics.

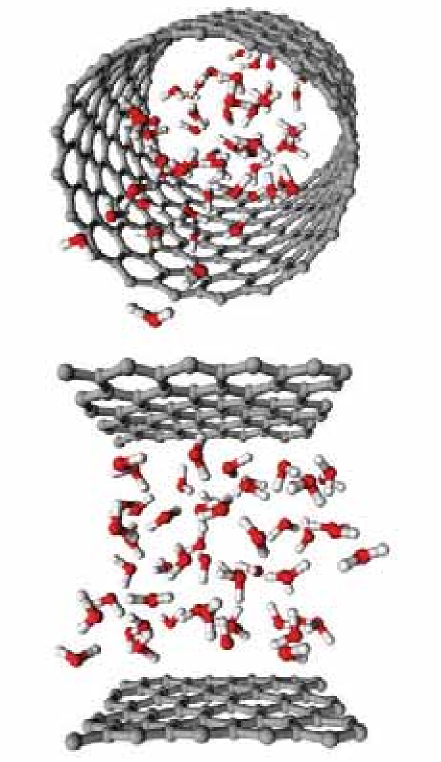
Because the properties of materials are important to almost all of the Laboratory's major programs, many grand challenge calculations are simulations of molecular dynamics. One important tool, named Qbox, uses the laws of quantum mechanics to describe the electrons in a system and then compute the interactions among atoms. Qbox makes possible predictions about material properties in cases where there are little data. Qbox on the Thunder machine can efficiently simulate hundreds of atoms for up to 20 picoseconds, allowing researchers to study nanotechnology, biochemistry, and high-energy-density physics. Qbox is also being optimized to run on the BlueGene/L supercomputer.

Researchers used Qbox to study the interaction between water and materials at the nanoscale. Their interest stems from plans to combine a nanoscale biological or chemical sensor with a nanofluidic device. Material properties change at the nanoscale, and subtle changes in a material's electronic and structural properties can be crucial to a device's performance. For example, simulations demonstrated that carbon tends to be hydrophobic, restricting the flow of water in carbon nanotubes or between closely spaced carbon graphite sheets. Results suggest that researchers may be able to prepare nanoscale materials with specific hydrophilic or hydrophobic properties.

Nanotubes are of particular interest for nanoscale electronic and mechanical applications because they are extremely



A simulation of the 1906 San Francisco earthquake is for a project with the U.S. Geological Service to better understand that quake and prepare for the next "Big One." For detailed simulations of the 1906 quake, see http://earthquake.usgs.gov/regional/nca/1906/simulations/.



Simulations of water molecules (red and white) confined within a carbon nanotube (top) and between carbon graphite sheets (above) demonstrate carbon's hydrophobic tendency.

strong and have good thermal conductivity. Researchers performed a series of quantum molecular dynamics simulations to examine the early growth of nanotubes, which must be carefully controlled for future applications. As reported in *Physical Review Letters*, the team studied different initial conditions of carbon covering nanoparticles of iron, which is a good catalyst for nanotube growth. They discovered that the carbon and iron do not mix at the nanoscale during growth and that the tubes grew capped.

New Supercomputing Tools

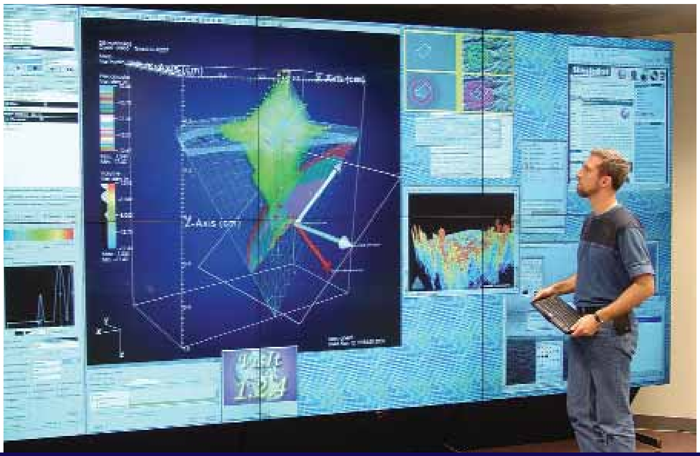
Scientific discovery through simulations requires more than codes optimized for highly parallel supercomputers; advanced tools for data management and visualization are needed as well. Laboratory users are benefiting from investments by the Advanced Simulation and Computing Program in new capabilities such as a powerful 256-node visualization cluster built by GraphStream Incorporated, which was delivered in September 2005. In addition, Livermore computer scientists are developing new knowledge extraction and visualization tools. One tool, dubbed VisIt, was an R&D100 Award winner in 2005 (see p. 49). Used to visualize data from a range of simulations codes, VisIt has a scalable architecture, allowing it to process some of the largest data sets ever generated.

Examining Materials Under Stress

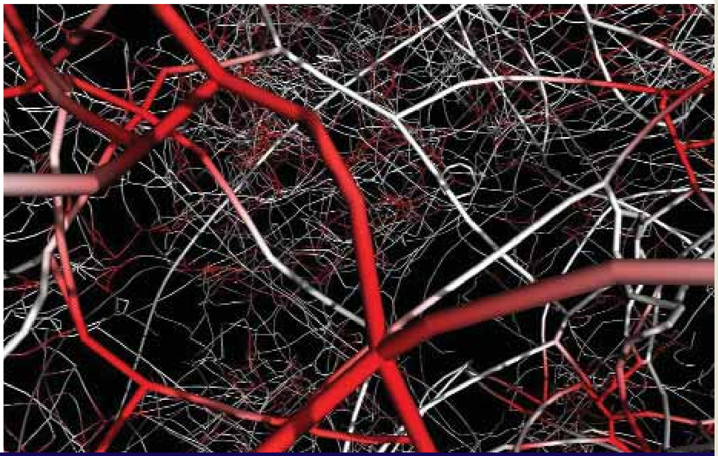
Experiments and advanced simulations are revealing further insights about material properties, especially in materials under stress. For wide-ranging applications, Livermore scientists need to understand what gives materials their strength and how and why they fail. Stockpile stewards, in particular, require detailed information about the properties of substances under extreme conditions.

In one set of activities, Laboratory scientists set out to better understand the mechanical properties of metals. The strength of most crystalline materials, including metals, derives from the motion, multiplication, and interactions of defects called dislocation lines. Simulations are providing unprecedented detail about dislocation dynamics—the interaction among dislocation lines. A new type of dislocation microstructure, known as a multijunction, was discovered through supercomputer simulations. The existence of multijunctions, which appear when three or more dislocations collide and form a knot, was confirmed in images taken with a transmission electron microscope. Multijunctions are thought to play an essential role in the strength evolution of crystalline metals as they deform.

Other research performed by a Laboratory-led team and reported in *Science* points to the possibility of making superhard materials. Metallic materials are made of small "grains" joined by grain boundaries, which limit the movement of defects when the metal is stressed. Nanocrystalline materials, with grain size of less than 100 nanometers, are much harder than ordinary materials. However, when the



The VisIt visualization program, with a scalable architecture to study extremely large data sets, won an R&D 100 Award.



A new code, the Parallel Dislocation Simulator (ParaDiS), reveals new details about dislocation dynamics, including the source of strength hardening in stressed materials.

A quantum molecular dynamics simulation of water molecules.

grain size is reduced to tens of nanometers, deformations occur in a different way: the grains slide over each other. Using Livermore's Janus laser, researchers exposed nanocrystalline copper to an intense shock wave (about one-megabar pressure), which created additional defects within and between grains. These defects prevented the grains from sliding. The hardness of the material increased between 10 and 20 percent with each laser shot. Supercomputer simulations both confirmed and offered greater insight into the experimental results.

A very common substance—water—was studied under extreme conditions. As reported in *Physical Review Letters*, a team of Laboratory scientists created "superionic" water by squeezing a sample in a diamond anvil cell to a pressure of 470 kilobars and using a laser to heat it to 2400º F. Expected to be found inside giant planets like Neptune and Uranus, superionic water is neither ice nor liquid. The oxygen atoms are nearly stationary, while the hydrogen atoms are extraordinarily mobile. The researchers measured the frequency of the water molecules' vibrations and saw an abrupt change as the temperature rose, signaling a phase change. The observed optical spectra data were consistent with computer simulations of superionic water performed using Qbox and Thunder (see p. 24).

Interstellar Dust in the News

An exciting year in astrophysics at the Laboratory began and ended with dust in the news. In the January 14, 2005, issue of *Science*, Laboratory researchers and collaborators offered an explanation for a 40-year-old enigma in astronomy—why interstellar dust absorbs light at a wavelength of 2,175 angstroms. Using the latest transmission electron microscope and a nano-secondary ion mass spectrometer, the team analyzed interplanetary dust particles collected from the stratosphere by a high-flying NASA aircraft. Within the particles, they found the carriers of the 2,175-angstrom feature: organic carbon mixed with amorphous silicate grains about 100 nanometers in size, common materials in interstellar space. The measurements provide important clues about how interstellar matter was incorporated into the solar system.

A year later, on January 15, 2006, the Stardust spacecraft returned to Earth, having collected more pristine dust samples from interplanetary space and the tail of the Wild 2 comet. The

A Laboratory scientist gives the thumbs up upon learning that the Stardust spacecraft had successfully captured interplanetary dust and brought it back to Earth for study.

The very young stars in Minkowski's Object (central white globule) are being formed by the interaction of gas with a radio jet (in red) emanating from a nearby radio galaxy.

particles were captured in a grid filled with silica-based aerogel developed by Laboratory researchers, who also designed technologies to extract the samples from the aerogel. Livermore is part of the NASA-led team now analyzing the dust.

Using many of the same analysis techniques, Livermore scientists and collaborators also examined the oxygen and magnesium content of inclusions in a meteorite. As reported in *Nature*, these new data allowed the team to better estimate the lifetime of the solar nebula, the mass of dust and gas that eventually led to the formation of the solar system.

Stars and Galaxies Shine

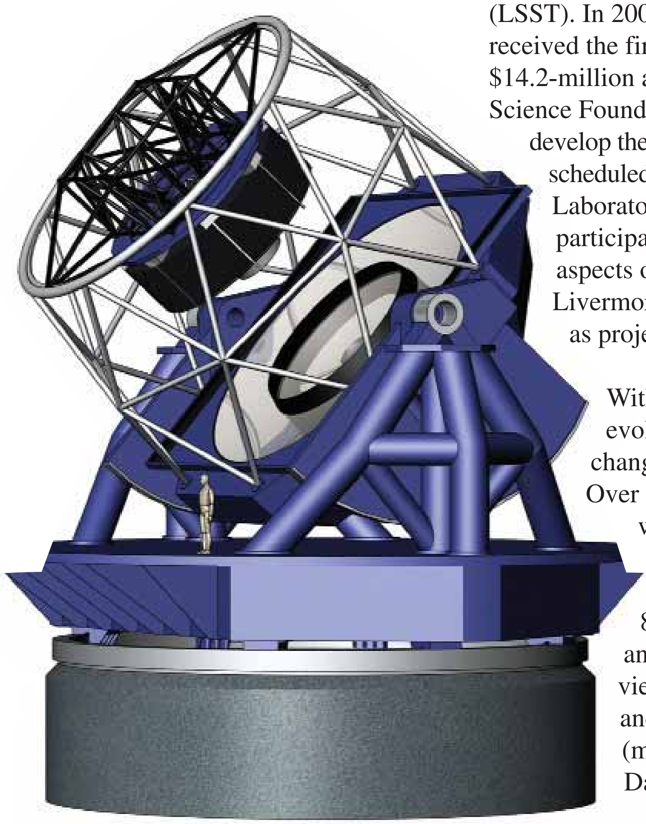
As reported in *Nature*, a Laboratory-led team has determined that stars form from the gravitational collapse of a gas cloud into massive clumps, which then evolve into stars. Through a series of supercomputer simulations, the team was able to rule out a competing theory, that the clumps are smaller and grow. Livermore's simulations show that turbulence in the gas cloud limits the rate at which clumps can accrete mass to become stars. Astronomers are observing too many stars in star-forming regions of the universe for the theory to be correct.

Laboratory researchers also combined computer simulations with optical and radio astronomy data to study and explain Minkowski's Object, a peculiar starburst system near the NGC 541 radio galaxy. In this system, perhaps 10 million stars are being created by a powerful jet of electrons, which is compressing warm, dense interstellar gas. The jet is emanating from the center of the radio galaxy where a black hole is accreting matter. This method of star formation is relatively rare today but may have been more common and significant in creating galaxies in the early universe. At that time, more hydrogen was available to create stars, and black holes were more active.

A New Window on the Universe

A very wide window for viewing the universe will open with construction of the Large Synoptic Survey Telescope (LSST). In 2005, the LSST project received the first part of a four-year, $14.2-million award from the National Science Foundation to design and develop the revolutionary telescope, scheduled for completion in 2012. Laboratory researchers are participating in virtually all aspects of the project, and a Livermore scientist is serving as project manager.

With its ability to record evolving events, LSST will change astronomy forever. Over a span of three nights, it will construct a complete, detailed map of the sky using a telescope with an 8.4-meter primary mirror, an extremely wide field of view (10-square-degrees), and an enormous camera (more than 3 billion pixels). Data from LSST's



The Large Synoptic Survey Telescope, which will map the entire sky every three nights, is expected to change astronomy forever.

astronomical surveys will be accessible almost immediately on the Web. When the telescope detects a changing object, such as an exploding supernova, it will send out an alert for more specialized telescopes to follow up with higher resolution images.

LSST will incorporate several technologies developed, for the most part, at the Laboratory. These include fabrication techniques for large optics developed for the recent generation of telescopes and the National Ignition Facility, the detector technologies for wide-angle cameras with billions of high-sensitivity pixels, and the technologies and tools for computing and storing large amounts of data (30 terabytes per night). Livermore helped pioneer wide-field-of-view, event-searching astronomy in the 1990s with the MACHO (Massively Compact Halo Object) project, which found evidence for one form of dark matter.

X-Ray Optics to Map the Sky

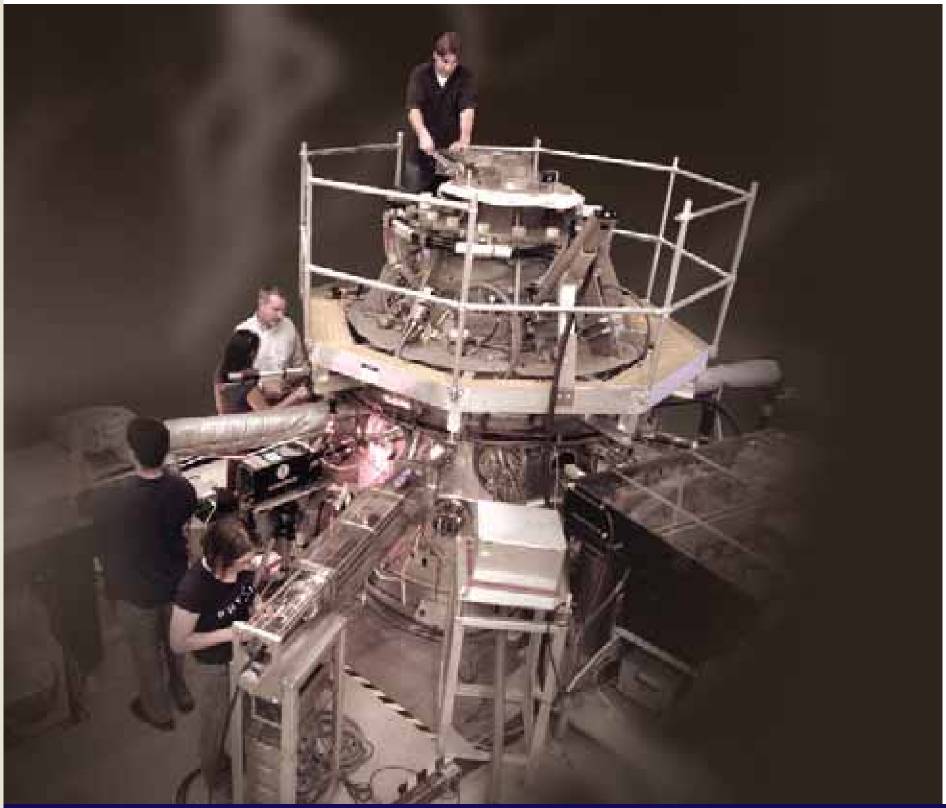
Livermore scientists are also engaged in programs to survey the sky in the hard x-ray (high-energy, greater than 20 keV) band of the spectrum. The Laboratory is part of a California Institute of Technology-led team proposing to build and launch a telescope named NuSTAR (Nuclear Spectroscopic Telescope Array), for which Livermore is contributing its special expertise in hard x-ray focusing optics. NuSTAR is part of NASA's Small Explorer Program, and a decision about proceeding to flight development is expected in early 2006.

NuSTAR's mission is to obtain a hard x-ray map of the sky in extraordinary resolution. Researchers intend to take a census of active black holes, which are powerful emitters of hard x rays, and they hope to measure the rate at which black holes are growing through the accretion of matter. Measurements of hard x rays from supernovae will also give scientists unprecedented information about physics deep inside exploding stars.

Laboratory scientists earlier worked with NuSTAR partners on the High Energy Focusing Telescope (HEFT), a balloon-launched hard x-ray telescope system. The Laboratory designed and fabricated the optics for the three telescopes and built the gondola. Launched on May 18, 2005, HEFT spent 20 hours nearly 40 kilometers above the Earth's surface, successfully imaging a dozen targets, including the Crab Nebula and the black hole Cygnus X-1. HEFT is providing the basis for the design and proposed production process for NuSTAR optics.

Fusion Energy Science Moves Ahead

The Laboratory is advancing fusion energy science through computational and experimental work performed for DOE's Office of Science. Livermore researchers are studying both the

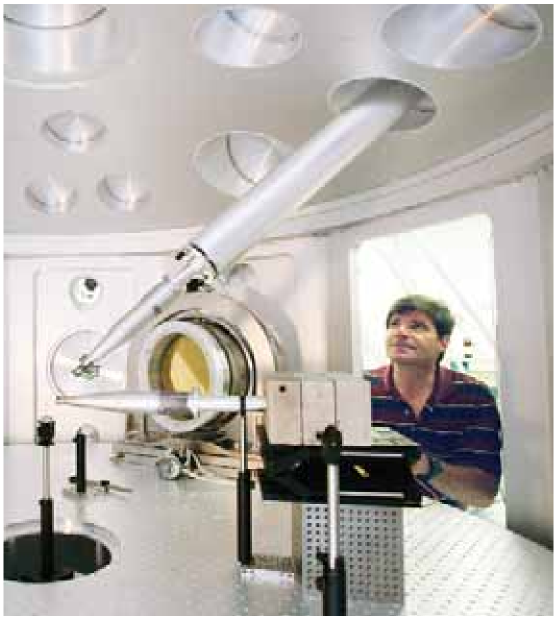


The "self-organizing" magnetized plasmas in the Sustained Spheromak Physics Experiment (SSPX) are similar to structures on the Sun and represent a possible route to fusion energy.

tokamak and spheromak approaches to magnetically confined fusion as well as inertial confinement fusion.

This year, an international agreement was signed to begin construction of the International Thermonuclear Experimental Reactor (ITER), a large tokamak designed to produce 500 megawatts of fusion power. The Laboratory has been participating in the ITER project since its inception. Livermore scientists working at the DIII-D Tokamak at General Atomics in San Diego have led the effort to develop new methods for reducing the heat load on the walls of ITER, and they are developing plasma diagnostics that the United States will install on ITER. In parallel, as part of DOE's Fusion Simulation Project, Livermore scientists are creating simulation tools to help understand how tokamak plasmas spontaneously form insulating surface layers. In these layers, plasma temperatures drop from more than 40 million degrees to a few thousand over a distance of just a few centimeters.

Livermore is examining an alternative to the tokamak concept at its Sustained Spheromak Physics Experiment (SSPX). The magnetized plasmas of a spheromak represent one possible route to commercial fusion energy, and the science of "self-organizing" magnetic dynamos is relevant to magnetic structures on the Sun and elsewhere. Research at the SSPX, which involves a large number of university collaborations, is aimed primarily at increasing the plasma's temperature and better understanding the role of turbulent magnetic fields in sustaining the plasma. Computer simulations at Livermore and Lawrence Berkeley National Laboratory's National Energy Research Scientific Computing Center are contributing to the study of the spheromak's exceedingly complex plasma behavior.



Using the Titan laser, researchers can explore high-energy-density physics issues, including the science of fast ignition for inertial confinement fusion.

One of many areas of exploration for inertial confinement fusion (see p. 10) is the concept of fast ignition. First, a nanoseconds-long, high-energy laser pulse compresses a deuterium–tritium capsule. Then a high-intensity picoseconds-long laser pulse acts as a sparkplug to ignite the deuterium–tritium fuel. In October 2005, Livermore dedicated the Titan laser, the Laboratory's first combined long-pulse (nanosecond) and ultra-short-pulse (sub-picosecond) laser. Operating with hundreds of joules of energy in each beam, Titan is one of only three petawatt-class lasers in the world. Researchers will perform a range of high-energy-density physics experiments at Titan, including exploration of the science of fast ignition. The world's first petawatt (million-billion watt) laser was built at Livermore in the 1990s.

New Technologies for Storing Nuclear Waste

A team of Livermore researchers is testing and refining the design and materials for what eventually may be 12,000 nuclear waste packages as part of the DOE's program to design, license, and build an underground nuclear waste repository in Yucca Mountain, Nevada. The repository would house more than 70,000 metric tons of spent nuclear fuel from civilian nuclear power plants and highly radioactive waste from defense-related activities at DOE facilities across the United States.

Livermore has been the long-time lead for the advanced materials science of the waste packages. A new award-winning technique (see p. 50) offers a much improved way to characterize the aging of materials that protect the waste package. The technique allows researchers to better analyze the different phases of metal that form in accelerated-aging and elevated-temperature experiments, and to compare the results to predictions.

As part of a multi-institutional effort, Laboratory researchers are also developing high-performance, corrosion-resistant materials. New iron-based amorphous metals can be applied as coatings with advanced thermal spray technology to prevent exposure to environments that might cause stress cracking. Such materials could be used to coat the outer surface of waste containers for spent nuclear fuel or to protect welds and heat-affected zones.

Understanding Global Climate Change

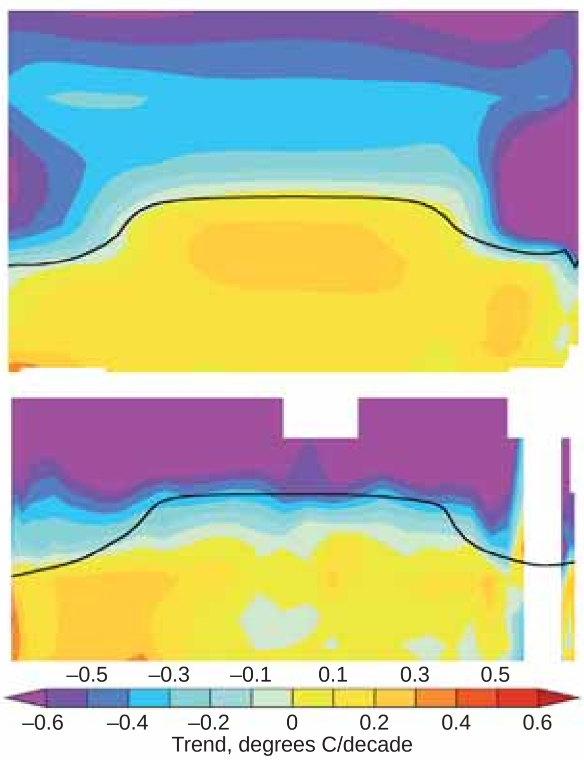
Three papers published in the August 11, 2005, edition of *Science Express* made an important contribution to the debate on global warming. The papers reconcile what had been a fundamental discrepancy between observed and modeled temperature trends in the tropical atmosphere. Until recently, climate modelers could compare their predictions of temperature increase with only one dataset, and those satellite observations showed a cooling of the tropical troposphere since 1979. The first two *Science Express* papers revisit temperature data obtained from satellites and weather balloons and provide compelling evidence that the tropical troposphere has warmed since 1979. The third study, led by a Laboratory scientist, finds that these new observational estimates of temperature change are consistent with the results from current climate models. Later in the year, that scientist, Benjamin Santer, was awarded a Distinguished Scientist Fellowship from the DOE Office of Science (see p. 48).

In another Laboratory-led study, researchers examined the consequences of humans continuing business as usual and using the entire planet's available fossil fuels by the year 2300. The polar ice caps will be depleted, ocean levels will rise by seven meters, and median air temperatures will soar to 8º C (14.5º F) warmer than today. The model predicts that the level of carbon dioxide in the atmosphere would rise from today's level of 380 parts per million (ppm) to more thsn 1,400 ppm by the year 2300. To the detriment of marine life, absorbed carbon dioxide would make the oceans more acidic. The results appeared in the *Journal of Climate*.

Managing Carbon

A variety of analyses, scientific studies, and technology development efforts at the Laboratory focus on the issues of carbon emissions and carbon management. To help energy futurists examine ways to reduce emissions, the Laboratory produces "U.S. Energy Flow Charts" each year and has done so for DOE since 1975. The charts, which are based on projections by the DOE's Energy Information Administration and other data sources, track energy supplies and demand. Data in the models also allow planners to study "carbon flow." Chart-making is now automated so that energy planners can study the implications of various what-if scenarios of energy supply, efficiency improvements, and demand.

A technique developed by two Laboratory scientists for reducing carbon dioxide emissions from power plants was patented in 2005. The process combines the carbon dioxide in power plant flue gas with water to produce a carbonic acid solution. The solution is mixed with limestone, which converts the acid to bicarbonate, and the bicarbonate is released into the ocean. Called carbonate weathering, the same geochemical reaction occurs in nature, only at a much slower pace. The process has less impact on marine life than the ongoing, passive uptake of excess carbon dioxide by



A Livermore-led team helped to reconcile the discrepancy between climate models (top) and weather balloon data (above) for temperatures in the tropical atmosphere.

the ocean or proposed injection of carbon dioxide into the deep sea.

A study published in *Nature* concludes that the Amazon basin is returning carbon to the atmosphere much faster than scientists had previously believed. Based on carbon-14 dating measurements at the Laboratory's Center for Accelerator Mass Spectrometry, the research team found that carbon being outgassed from Amazon waters has been stored in the surrounding landscape for only about five years. Previous measurements indicated that the age of carbon in the downstream sections of the Amazon basin was from 40 to more than 1,000 years.

Energy flow charts help visualize energy supply and demand, and their data allow planners to study "carbon flow."

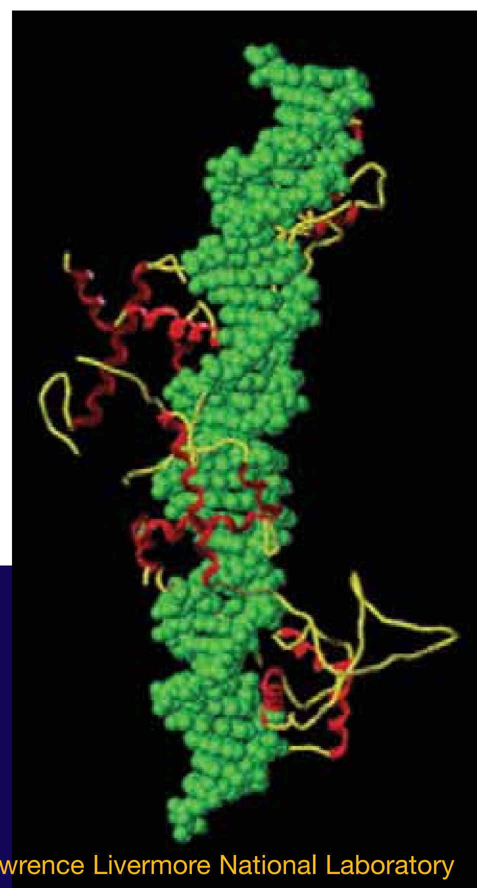
Focus on the Genome

Biology has been playing a growing role in the Laboratory's interdisciplinary research in recent years, for which the emphasis on biodetection and biodefense (see p. 19) is partly responsible. In addition, since the completion of the Human Genome Project, Livermore continues to be a leader in genomic research.

Laboratory scientists aim to determine the molecular functions of microbes that help regulate the planet's environment. One such study examined a community of microbes that thrives in hot, highly acidic conditions. Researchers from Lawrence Livermore and Oak Ridge national laboratories, the University of California at Berkeley, and Xavier University in New Orleans studied an Environmental Protection Agency Superfund site at an abandoned mine at Iron Mountain, California. There they identified more than 2,000 proteins, more than 400 of which appear to be unique to this community. Their research, reported in *Science Express*, was the first to gather information on genes that are expressed within a natural community.

The field of comparative genomics is benefiting from work by a Livermore-led team of researchers. They developed analytical and visualization tools for identifying conserved DNA sequences, including gene regulatory elements that control gene expression and thereby play a major role in gene function and mechanisms of disease. These regulatory sequences are particularly enriched in "gene deserts," the large, mostly barren strings of DNA between genes. In one study, published in *Genome Research*, the researchers characterized especially large gene deserts that have persisted for hundreds of millions of years of evolution. Their new Web-based tools, which search all available sequenced genomes for regulatory elements, are now being used by medical and biological researchers worldwide as a resource for understanding genome function in many different species.

In another project related to gene expression, a team led by scientists from the Laboratory and Uppsala University in Sweden has developed a new bioinformatics technique for systematically analyzing key regions in DNA that help control gene activity. Binding sites, where DNA interacts with the proteins that control gene expression, can be far away from the genes they influence. Gene expression may also be controlled by several regulatory proteins (known as transcription factors) working



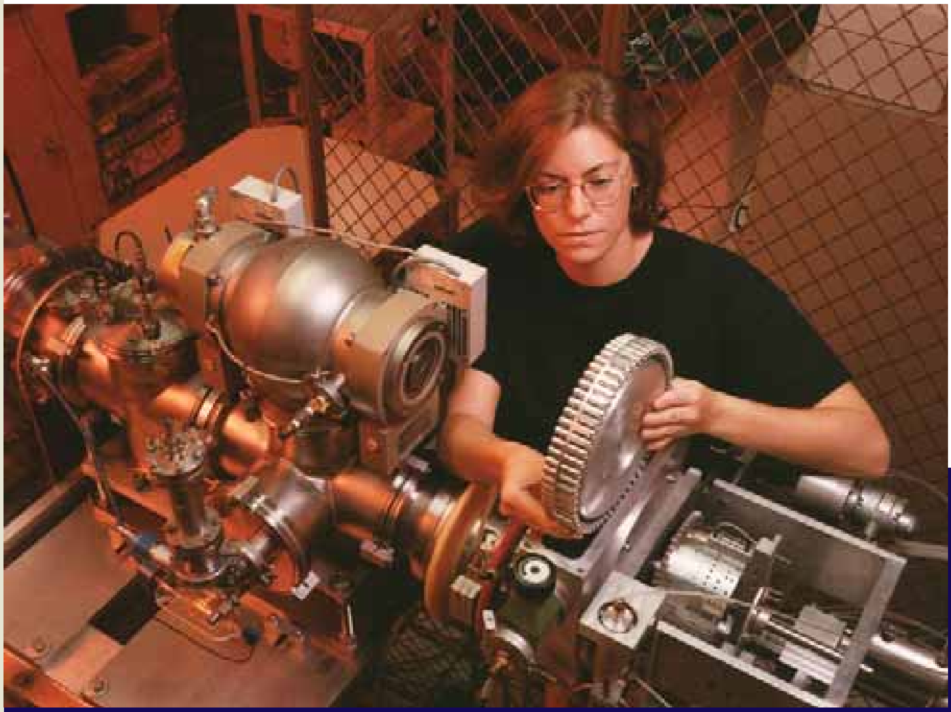
A new bioinformatics tool can locate sites where DNA interacts with proteins that control gene expression. Work started with much-studied yeast, including the yeast telomere-binding protein RAP1.

together at various binding sites. A machine-learning technique called rough sets mathematically modeled rules that associate known binding sites and gene expression in yeast, one of the most widely studied organisms. The team found that the same transcription factors, in slightly different combinations, could be responsible for the regulation of different genes. A large number of expression outcomes are possible using relatively few transcription factors.

Advanced Techniques Offer New Insight

Well established experimental tools are being used in new ways to offer insight into important materials and natural processes. An example is the accelerator at the Center for Accelerator Mass Spectrometry, which is commonly used for carbon dating of archaeological and paleontological samples. In 2005, researchers used it to measure the age of DNA in human cells and tooth enamel. Swedish forensic scientists, who teamed with Livermore on the tooth enamel research, used enamel dating to help narrow the search for victims of the December 2004 tsunami in Southeast Asia.

Laboratory researchers combined breast cell-based assays with computational modeling and nuclear magnetic resonance (NMR) to better understand the link between the human diet and breast cancer. In this study, they examined a class of tumor-causing mutagens created when muscle meats such as beef, pork, and fowl are cooked. These mutagens, known by the acronym PhIP, may cause tumors in laboratory animals. The Livermore team developed methods that use NMR—most often used to determine the structure of proteins—to study whether molecules compete for the same binding location on a protein. NMR experiments confirmed simulation results that PhIP binds to the estrogen-receptor protein, activating estrogen receptors and stimulating breast cancer cells to proliferate. Understanding how diet affects the growth of hormone-sensitive cancers may eventually lead researchers to potent new therapeutics.



A Precise Measurement of a Basic Theory

Laboratory researchers tested quantum electrodynamics (QED)—an extension of quantum mechanics—to 10 times greater precision than any other recent measurements. The scientists entered a new realm in the search for QED deviations by measuring light generated in the extreme electric fields surrounding the nucleus of uranium. Deviations from QED would have far-reaching consequences for understanding the universe because they would indicate that QED is not in fact a fundamental theory of nature.

The team tested the theory using Livermore's SuperEBIT, an electron beam ion trap that strips atoms to a highly ionized state and holds the matter in place for hours while researchers study the emitted radiation. In the experiments, uranium atoms were stripped of all but three electrons, forming a uranium plasma. High-precision spectroscopy measurements allowed the team to extract an experimental value for the new QED effects, in which the polarized vacuum and the self-energy interacted with each other and themselves. Previous measurements only tested the noninteracting manifestations of QED. The team's results, which appeared in *Physical Review Letters*, will likely stimulate new experimental testing of QED predictions.

Discoveries at the Center for Accelerator Mass Spectrometry were cover news in three scientific journals in 2005.

Laboratory Operations

Because safe, secure, and efficient operations are an integral part of Livermore's research and development programs, responsible stewardship of the Laboratory entails setting high standards in all aspects of operations. Together, quality operations and scientific and technical excellence make possible Livermore's programmatic accomplishments and sustain public trust in the Laboratory.

Safety and security are the most important considerations in day-to-day operations. The Laboratory provides employees and neighboring communities with a safe and healthy environment in which to work and live. All employees hold a personal commitment to the safety of their work and of the individuals around them. The Laboratory is continuously improving systems in place to assure that proper safety practices are learned and followed by all. Security, also the responsibility of every employee, requires vigilance. Nuclear materials, sensitive information, and other valuable assets must be protected against new and evolving threats.

Business processes and systems, infrastructure management, and administrative functions are continually being improved to achieve best-in-class among high-technology research organizations. The demand is greater than ever before to improve efficiency and cut costs while maintaining compliance in an increasingly complex regulatory environment. A strategic, institutional view is needed to set priorities regarding where and how to improve work processes. A major challenge is effectively measuring performance to gauge success and providing quality assurance to Laboratory and contract managers, government officials, and the general public.

Safety is Number One

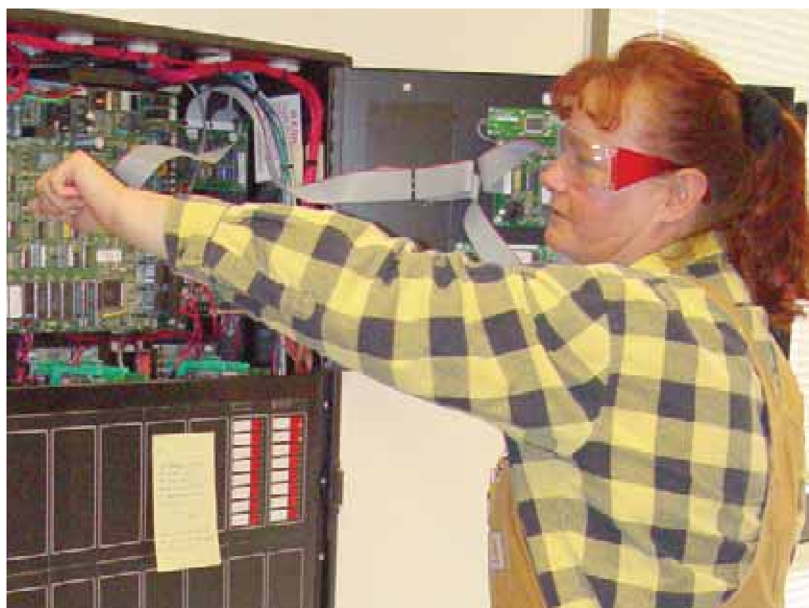
The Laboratory has put into place effective systems and procedures to assure that safety standards are met. Through the Integrated Safety Management System (ISMS), safety procedures and practices have markedly improved, as has safety performance. An audit report from the Department of Energy's (DOE's) Office of Independent Oversight and Performance Assurance (OA-40) in January 2005 states that "Managers and staff demonstrated a strong commitment to safety and reducing injuries and operational events. Most work activities observed were performed with a high regard for safety."

Illness and injury rates continue to decline at the Laboratory. For fiscal year 2005, the rate for recordable cases (number of cases per 100 employee-years) was 2.45 percent, and the rate for cases with days away, restrictions, or job transfers was 0.72 percent. These rates are comparable to those of best-in-class companies. In the area of electrical safety, Livermore's safety program has been identified by DOE as a model for the entire nuclear weapons complex. Excellence in safety is exemplified by the National Ignition Facility's five-year record of more than 4.5 million consecutive hours of work without a lost work day from an on-the-job injury. Plant Engineering crafts personnel have also worked more than 1.6 million consecutive shop hours without a lost work day.

A commitment to safety at all levels of management and by every individual is key to continuing success. The institution and each of the directorates are improving their abilities to identify their own weaknesses, analyze safety implementation, and develop effective corrective actions. The Laboratory has enhanced its self-assessment requirements to ensure more consistency, rigor, and oversight. Line managers are conducting observations of working-level activities to help identify improvements to the implementation of ISMS. In addition, a new Office of Institutional Performance Analysis was established to develop and communicate timely information to facilitate more effective management decision making, prevent recurring events, and improve efficiency.

Livermore has strengthened the safety of its nuclear facilities. The Laboratory stood down the Plutonium Facility (Building 332, also known as the Superblock) to assess all activities, develop new tools and processes, and implement rigorous protocols for resuming work. As a result of this effort and the cooperative support of the National Nuclear Security Administration's Laboratory Site Office (NNSA LSO), the Superblock

Safety comes first for crafts personnel at the Laboratory, who have worked more than 1.6 million shop hours without a lost work day.



Livermore's program for electrical safety has won accolades from DOE.

has returned to operation. An integrated, resource-loaded schedule has improved communication and the timely implementation of essential projects as priorities evolve. Another major nuclear facility at the Livermore site, Building 251, was successfully decommissioned (see p. 37). In addition, the Laboratory is pursuing all actions required to ready the Device Assembly Facility at the Nevada Test Site as a Category 2 Nuclear Facility. The Device Assembly Facility is managed by Livermore for NNSA.

The DOE Office of Independent Oversight and Performance Management (OA-30) recognized improvements to the Laboratory's Emergency Management Program. Their June 2005 report stated that Livermore "…has developed a rigorous framework for the emergency management training, drill, and exercise program." The performance demonstrated in the Laboratory's 2005 emergency response exercise and post-exercise improvements give confidence that Laboratory workers and the public would be protected from potential consequences of an incident involving hazardous materials.

Security Improvements

Security was enhanced after the September 11 attacks, and Livermore now operates routinely at a heightened security level. An extensive security apparatus is in place, and adjustments and upgrades are continually made to address new threats and concerns. The LSO's *2004/2005 Annual Safeguards and Security Survey of Lawrence Livermore National Laboratory* gave Livermore a Satisfactory rating, the highest rating possible.

Effective implementation of Livermore's Integrated Safeguards and Security Management (ISSM) helps to ensure that security is a top priority for all employees. Individual and collective responsibilities for safeguards and security are made clear to Laboratory personnel, who are required to complete necessary training. Line management in each directorate is accountable for performance and conducts an annual self-assessment in the areas of classified removable electronic media, locks and keys, security incident prevention, and implementation of ISSM.

The Laboratory is making continual improvements in cyber security, material control and accountability, counter-intelligence, and physical protection. In particular, the Protective Force Division is staffing up and has implemented an alternate work schedule to reduce overtime. The division's overall operational readiness metric, which measures staffing, tactical training, overtime, equipment, and fitness, continues to improve. In 2005, the metric exceeded the Laboratory's internal goal of 85 percent. Equally important, an NNSA validation team described Livermore's use of technology to meet threat requirements as "best in complex."

Responsible Environmental Management

The Laboratory's commitment to environmental management is exemplified by the receipt of two

These newly graduated protective service officers add to the staff that provides physical security at the Laboratory.

The Decontamination and Waste Treatment Facility helps ensure that the environmental impact of Laboratory waste is minimal.

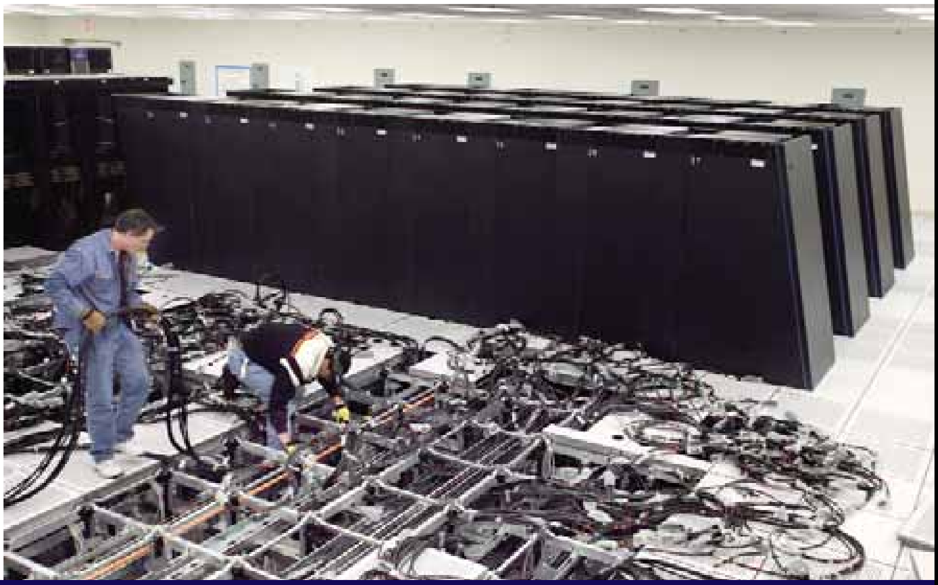
Pollution Prevention awards from DOE/NNSA in 2005. One award was for instituting a rigorous system for characterizing a waste stream, segregating acutely/extremely hazardous materials, and certifying the residual as low-level waste. By means of this system, the Laboratory has been able to divert about 44 percent of its waste (by mass) from mixed waste to low-level waste, which can be disposed of at the Nevada Test Site.

With support from Livermore staff, DOE completed the *Site-Wide Environmental Impact Statement* for continuing operation of the Laboratory. The Laboratory also integrated the International Organization for Standardization (ISO) 14001 environmental management system into ISMS. Academic, manufacturing, and government organizations worldwide have been adopting ISO 14001 as an effective management tool to help them analyze, measure, control, and minimize potential environmental impacts from their operations.

Livermore's environmental management efforts include remediation of groundwater contaminated many decades ago and disposal of legacy waste. In fiscal year 2005, Livermore met all negotiated, enforceable environmental restoration milestones as agreed to under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). In addition, 682 drums of transuranic (TRU) waste were removed from the Laboratory site. This legacy TRU waste had accumulated during decades of weapons program activities. Working in partnership with DOE, Livermore shipped this material to the Waste Isolation Pilot Plant near Carlsbad, New Mexico. The operation included 18 shipments with drums packed in specialized containers that weighed more than 7,000 kilograms.

In with New Facilities, Out with the Old

Construction of the $91-million Terascale Simulation Facility was completed well ahead of schedule and within budget. Occupation and activation of the building were completed in spring 2005. The 253,000-square-foot facility is home to the Laboratory's two large classified



BlueGene/L was one of two supercomputers installed in the new Terascale Simulation Facility.

supercomputers, ASC Purple and BlueGene/L (see p. 9); an advanced simulation laboratory for development of data assessment hardware and software; and offices for up to 288 staff members. The expeditious move of personnel and equipment to the new building was accomplished with no safety or security incidents. The move resulted in only short (one- to two-day) network-wide downtimes for unclassified and classified Livermore computing customers.

A nearly three-year effort to clean up Building 251, the Heavy Element Facility, reached a major milestone in April 2005 when the structure's status was downgraded from a Category 2 Nuclear Facility to a Radiological Facility. This change will save the Laboratory more than $250 million. No longer needed for heavy-element research and support for nuclear testing, the building had been on standby status since 1995. Nevertheless, significant upgrades would have been necessary to bring the facility into compliance with new requirements for a Category 2 Nuclear Facility.

Livermore met the deadline to downgrade the facility by April 10, removing stored heavy-element materials, 40 glove boxes, and associated ventilation systems. Altogether, the team removed 487 waste parcels packaged in 84 TRU waste drums, 38 Minimal Detectable Activity waste parcels, and more than 110 other items. The project was completed with virtually no safety incidents.

Cleanup of the Heavy Element Facility allowed its status to be downgraded to a Radiological Facility, saving the Laboratory millions of dollars.

Firefighters in Action

Suppressing a wildfire in the Altamont Hills that began during the evening of July 19, 2005, required 650 firefighters from the Laboratory, California Department of Forestry, the cities of Livermore-Pleasanton and Tracy, and Alameda and San Joaquin counties. They fought overnight to put out the fast-moving blaze, which grew to 10,000 acres and spread onto Site 300, the Laboratory's experimental test facility 15 miles southeast of the main Livermore site.

Laboratory firefighters Arnie Brockmire (left) and Kenneth Rinna spent two weeks in New Orleans rescuing survivors of Hurricane Katrina.

No facilities at Site 300 were damaged, and no one was injured. The fire station at Site 300 is staffed to handle such events, and the coordinated response to the fire ensured that the Laboratory's personnel and facilities were well protected. The Alameda County Fire Department served as incident command, operating out of the Site 300 fire station.

After Hurricane Katrina struck, two Laboratory firefighters were part of a 14-member squad from various Alameda County fire departments sent to New Orleans. In more than two weeks of assistance, the squad performed more than 980 rescue missions, including rescuing 100 children separated from their parents. The Laboratory's firefighters were sent in response to a Federal Emergency Management Agency request for swift-water rescue

Livermore's business practices and systems are continually being improved, with a Process Improvement Initiative serving as catalyst.

personnel. Staff from the Health Services and Hazards Control Departments were also deployed to provide medical assistance to evacuees.

Efficient and Effective Business Practices

The Laboratory's business systems—procurement, property management, and finance—are designed around best-in-class business practices and applicable federal regulations. Each area has performance management programs in place that include metrics and performance thresholds, which were developed in concert with NNSA and the University of California. Of particular note, Laboratory Procurement underwent an independent system assessment in August 2005 by a Procurement Evaluation & Engineering Team composed of NNSA officials and contractors. The team identified eight best practices, many procurement operation strengths, and no significant findings. In addition, 17 audits and reviews of Livermore's financial management practices were conducted by various internal and external organizations. No significant deficiencies were identified.

Business processes and systems are continuously improved to increase effectiveness and lower overall institutional administrative costs. Taking advantage of information technologies, the Laboratory is re-engineering many processes, including the development of new electronic systems for travel reimbursement, purchase ordering, account management, and recruitment and hiring. A Process Improvement Initiative, now in its second year, is serving as a catalyst to stimulate continual improvement as a shared Laboratory value. Livermore staff members trained in process improvement methods are assisting organizations that have identified key opportunities and needs for process improvement, helping to increase efficiencies and lower costs.

With an eye on future needs and requirements, the Laboratory is also investing in business projects that will transform the way work is done. One management initiative is the People Information Program, which will consolidate personnel information into a single database to enhance human-resource administrative functions at the Laboratory. Estimated operational savings will exceed $15 million per year when the project is fully implemented in two years. A second major effort, the Enterprise Project Accounting and Reporting (EPAR) Project, is in the initial development phase. When completed, EPAR will give Laboratory project and program managers a comprehensive, integrated toolkit for meeting planning, tracking, and reporting requirements. EPAR is expected to save the Laboratory about $19 million per year.

Outreach and Partnering

With outstanding scientific and technical capabilities and an important national security mission, Lawrence Livermore National Laboratory is a national resource. The Laboratory's continuing success in understanding emerging national needs and technical opportunities depends on engaging sponsors and actively participating in the broad scientific community. Success in the Laboratory's research programs depends on strong ties to research universities and partnerships with U.S. industry.

The Laboratory's closest academic ties are with the campuses of the University of California (UC). In addition to more than 500 ongoing collaborations between Laboratory scientists and UC colleagues, joint research programs foster interdisciplinary collaborations. These academic partnerships strengthen research programs at Livermore and the campuses. University ties also serve as a valuable pipeline for recruiting new talent to the Laboratory. Partnerships with U.S. industry bring valuable research tools to Livermore programs—from the world's fastest computers to the world's largest laser. Industrial partnerships also lead to the transfer of the Laboratory's technological advances to the marketplace.

Lawrence Livermore is an important regional resource, too, contributing to the intellectual vitality of the San Francisco Bay Area and the San Joaquin Valley. Being a good neighbor is important to the Laboratory and its employees. As an institution, the Laboratory provides Californians with information and expertise on a variety of issues ranging from homeland security to groundwater management. Livermore partners in an array of educational, business development, and diversity outreach programs. The Laboratory supports a wealth of K–12 and community college science education programs and works with local universities and colleges. The Laboratory's 8,000-plus staff members and their families also contribute individually to the well-being of neighboring communities through charitable contributions and volunteer work.

The World Year of Physics at Livermore

The Laboratory celebrated the World Year of Physics with Science Week in May and special events throughout the year to mark the 100th anniversary of Einstein's four seminal, revolutionary papers. The legacy of this miraculous year lives on at Livermore, with the Laboratory at the forefront in many related research areas—from relativistic astrophysics to fusion energy research ($E = Mc^2$).

Research ties to Einstein's breakthroughs were featured on Science Day to open Science Week. Laboratory employees and honored guests from DOE, NNSA, and UC filled the auditorium to hear presentations by notable visiting and Livermore scientists. Many World Year of Physics activities were aimed at science education for neighboring communities, while other events were available for staff members.

Science Week included Community Leader Day, an opportunity for neighboring guests to tour research facilities, converse with Laboratory managers and staff, and join in the World Year of Physics celebrations. The more than 180 visitors were welcomed by Jerry Paul, principal deputy administrator for NNSA; Admiral Robert Foley, UC vice president for Laboratory Management; and Laboratory senior managers. A poster session and Laboratory tour included opportunities to learn about projects in homeland security and bioscience and to visit the Terascale Simulation Facility, the National Ignition Facility, and the Center for Accelerator Mass Spectrometry. The day gave guests a broad view of the Laboratory and its programs and plans and gave Laboratory leaders an opportunity to hear about important community issues.

To celebrate the World Year of Physics, (clockwise from top) Community Leader Day brought local mayors and others to the Laboratory, "Einstein" chatted with a Laboratory manager, and "Einstein" helped judge the egg drop contest for school children. A Web site kept the public and employees informed of events.

Expanding Efforts in Science Education

The Laboratory's science education programs and activities reached about 12,700 students in 2005, 20 percent more than in 2004. The programs are many and diverse: the Science on Saturday lecture series, the Expanding Your Horizons in Math & Science career conferences for young women, the School Tour Program for fourth and fifth graders, the Fun with Science traveling science show, Engineers Day, the Tri-Valley Science & Engineering Fair, and Got Science? Discover Science Saturday for students and parents.

Many programs featured the World Year of Physics theme. For example, the Laboratory, in partnership with the UC Office of the President, hosted Frontiers of Physics for 350 high school science students. The event featured speakers from the university and the Laboratory, a young scientists career panel, program displays, a tour of the National Ignition Facility, and an opportunity for students to talk with UC campus representatives. Also in 2005, the Laboratory and Livermore Valley Joint Unified School District signed a memorandum of understanding to work together to enhance science education in the district.

The Laboratory's Edward Teller Education Center (ETEC) is home for a wide variety of professional development programs for K–12 and community college educators. Sponsored by the Laboratory, the UC Office of the President, UC Davis, and UC Merced, the center aims to improve the quality of science instruction and technology applications in the classroom. In February and March, ETEC and the Laboratory conducted special teacher development workshops in partnership with Alameda County Supervisor Scott Haggerty and Congressman George Miller (7th District, California). The sixth annual Edward Teller Science & Technology Education Symposium, a two-day event held in September, was attended by more than 200 California teachers. The participants received up-to-date science information in topical areas as well as lessons and activities for use in the classroom. Other activities at ETEC included computer technology workshops and a Teacher Research Academy in July in the areas of

During a Fun with Science presentation, ninth-graders from Oakland learned about atmospheric pressure (top). Students analyzed an unknown powder found at a mock crime scene during the annual Science Adventure Institute in Livermore (SAIL) (above).

Three local high school students were winners of the Edward Teller Science Scholars awards, which are scholarships given to graduating seniors who excel in science studies.

biotechnology, biophotonics, and environmental science.

In a review of these programs by the Secretary of Energy Advisory Board (SEAB) education outreach subcommittee, Livermore's programs were found to be of high quality and to exemplify many best practices for other government education programs.

A Good Neighbor

The success of the Laboratory's educational outreach programs depends on the more than 500 staff members each year who volunteer their time and serve as science lecturers, mentors, science fair judges, and presenters or instructors in workshops and classrooms. Livermore employees also engage in other outreach activities through participation in community assistance and economic development organizations. The Laboratory's *Community Report*, available from the Public Affairs Office and online, summarizes the many ways the institution and Livermore employees benefit neighboring communities.

The Laboratory's Help Others More Effectively (HOME) campaign raised about $1.5 million for Bay Area and San Joaquin Valley charitable organizations in 2005. Livermore employees marked their seventh straight year of contributions totaling more than $1 million. The Laboratory is the largest single workplace supporter of the Tri-Valley Community Fund, which is dedicated to raising and distributing local charitable contributions to human service, educational, cultural, and recreational organizations. As part of the HOME campaign, employees also raised over $75,000 for Hurricane Katrina relief.

Helping Ensure Clean, Reliable Water Supplies

Water management is one research area where Laboratory science and technology development programs apply directly to regional issues. Livermore is creating tools that will help water resource managers make the best decisions about California's water supply infrastructure, protection, and treatment.

As an example, the Laboratory is working with the State Water Resources Control Board in the Groundwater Ambient Monitoring Assessment (GAMA) project. Livermore is applying its state-of-the-art facilities for age

Holiday gifts for the less fortunate are one of the ways that Laboratory employees contribute generously to the community.

The Groundwater Ambient Monitoring Assessment project makes use of this State of California-certified environmental analysis facility at Livermore.

dating tritium (helium-3 presence) and methods for low-level detection of tracers and contaminants to detect migration. Integrated with high-resolution hydrologic models, these capabilities are aiding California in assessing groundwater vulnerability to MTBE, nitrates, and other contaminants. The work during the next five years will focus on 116 priority groundwater basins that account for 90 percent of the state's groundwater use. Laboratory scientists will analyze and interpret the results from samples taken from selected municipal water supply wells and provide the results to the State Water Resources Control Board and the U.S. Geological Survey.

Research Collaborations With University of California

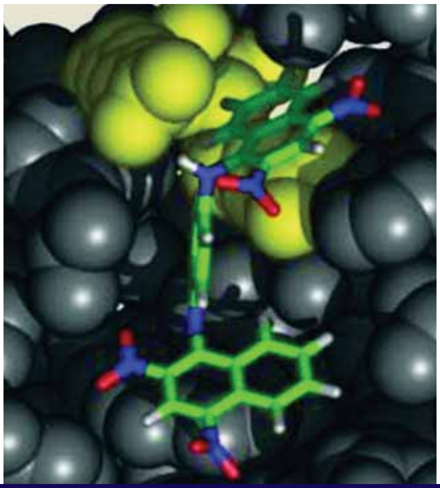
Collaborations between the Laboratory and UC campuses serve to strengthen research programs at Livermore and provide the campuses with access to Livermore's multidisciplinary capabilities and special research facilities. More than one-quarter of the roughly 1,000 peer-reviewed journal articles produced each year by Laboratory scientists are coauthored by colleagues at UC campuses. Larger-scale collaborations take place through partnerships in research institutes on campuses and at the Livermore site.

One of the Laboratory's many strong ties with UC Davis is the UC Davis Cancer Center, a National Cancer Institute-designated center. In 2005, the National Cancer Institute (NCI) renewed the designation for five years and provided $14 million in new federal funding through 2010. The UC Davis Cancer Center's program now comprises about 180 scientists at work on more than 300 cancer projects on three campuses, including the Laboratory. The center's partnership with Livermore, the first of its kind in the nation, was a key factor in first winning the NCI designation in 2002. In the partnership, physicians and scientists are turning technology developed for national security into new cancer therapies, detection methods, and prevention strategies.

An exciting area of collaboration is the design and application of SHALs (synthetic high-affinity ligands) to fight cancer. SHALs are tiny molecules specially designed to bind to unique sites on the surfaces of proteins. A Laboratory researcher conceived of SHALs to bind to potential bioterror agents like botulism or anthrax, quickly and efficiently detecting and neutralizing them. Now his team is designing SHALs that bind to "activated" receptors in cancer cells. With this tool, physicians can better assess the likelihood of rapid cancer growth and fight the disease.

Livermore and cancer center researchers are also using atomic force microscopy and computer simulations to provide a reliable new technique to characterize

Lawrence Livermore is a research partner in the UC Davis Cancer Center, a National Cancer Institute-designated center.



In collaboration with the UC Davis Cancer Center, nanometer-size molecules are being designed that bind to lymphoma cell proteins and inhibit the rapid cell growth of cancer.

the binding interaction between peptides that are cancer markers and antibody fragments that mimic the architecture of a cancer drug. The aim is to improve targeted drug delivery in cancer treatment. Another collaboration applies Livermore's accelerator expertise to the development of a small, inexpensive proton accelerator system for radiation therapy that targets only tumors, sparing surrounding healthy tissue. Because proton radiotherapy systems today are the size of stadiums and cost more than $100 million, this new system could revolutionize radiation therapy.

The Laboratory is assisting in the establishment of UC Merced, the nation's first new public research university of the 21st century. The UC Merced campus opened in September 2005 and will eventually be home to 25,000 students and 6,600 faculty and staff. The university has a close affiliation with Livermore, and its research areas are being aligned with the Laboratory's in a number of areas. In one strategic collaboration, for example, Livermore staff are working with UC Merced faculty on regional environmental research.

Laboratory Technology in the Marketplace

In 2005, Livermore scientists and engineers—and their research partners—earned four R&D 100 awards. Each year, *R&D Magazine* presents awards to the 100 top technological advances of significant potential benefit to society. Since 1978, Laboratory researchers have won 106 R&D 100 awards, and many of these inventions were developed in partnerships or have been transferred to U.S. industry for commercial development. In 2005, the award winners included two systems developed for homeland security, the bioaerosol mass spectrometry system (BAMS, see p. 20) and the adaptable radiation area monitor (ARAM, see p. 18). The VisIt visualization tool (see p. 25), used to process gigabytes of data in useful graphic forms, was also honored.

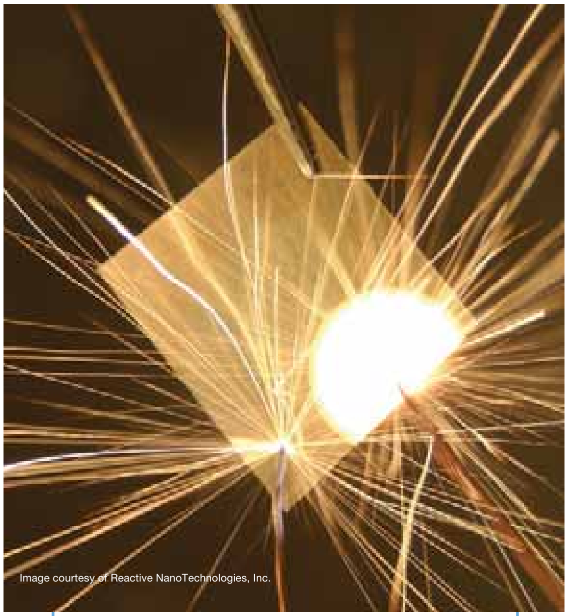


Image courtesy of Reactive NanoTechnologies, Inc.

An R&D 100 Award winner, NanoFoil® can "solder" components together with no thermal damage.

The fourth R&D 100 Award winner, NanoFoil®, was featured on the cover of the *Strategic Plan for the National Nanotechnology Initiative*, issued by the Executive Office of the President. NanoFoil is a revolutionary product to metallically bond a small component to another item—such as a computer chip to a heat sink—with no thermal damage. The foil consists of thousands of nanolayers of nickel and aluminum that chemically react when pulsed with energy. The reaction heats the surrounding solder material in a controlled manner. NanoFoil grew out of technology at the Laboratory to fabricate multilayer x-ray and extreme ultraviolet optics. It was developed in partnership with researchers at Johns Hopkins University and Reactive NanoTechnologies in Hunt Valley, Maryland, which manufactures and exclusively sells NanoFoil.

UltraCell Corporation of Livermore, California, has developed a portable fuel cell that could power a laptop computer for an entire day without recharging. UltraCell's new fuel cell has twice the energy density of standard lithium batteries and can provide continuous power at remote locations. Users can swap out the methanol fuel canisters for fresh fuel while the computer is in use. UltraCell has an exclusive licensing agreement to use Laboratory-developed micro-fuel-cell technologies, including a microreformer, a microelectromechanical system that converts methanol fuel to hydrogen. Through many other license agreements, numerous Laboratory-developed products are now in the marketplace, earning licensees revenues estimated at more than $300 million.

People and Management

Livermore's most valuable asset is its workforce. The Laboratory stays vibrant by attracting and retaining a high-quality workforce motivated by "passion for mission" and dedicated to excellence. Highly motivated individuals and exceptional multidisciplinary team efforts are responsible for achieving program goals in 2005, advancing science and technology, and continually improving operations. Laboratory staff are carrying forward a long tradition of scientific and technological innovation to meet pressing national needs. The strength of the current workforce is demonstrated by the many awards for scientific accomplishments and quality operations.

Strong ties to world-class research universities—and in particular many partnerships with the various campuses of the University of California (UC)—serve as a vehicle for bringing new talent to the Laboratory. Much of Livermore's work requires special skills. Scientists and engineers gain essential expertise through years of training, working with senior staff, and access to unique computational and experimental capabilities. The Laboratory's continuing success depends on providing employees with abundant career development opportunities, a quality work environment, and the chance to work on projects that make a difference to the nation.

Livermore's long-standing ties with UC have also fostered a tradition of intellectual independence and integrity, as well as a focus on the long-term interests of the nation. Laboratory researchers strive to anticipate future national needs and security threats. Science and technology investments and exploratory research and development efforts are targeted accordingly. Visionary technical leadership and effective management of research programs and operations underpin Livermore's achievements and sustain public trust in the Laboratory.

Contract Competition for Los Alamos and Livermore

The University of California has managed and operated Berkeley, Livermore, and Los Alamos national laboratories on behalf of the federal government since their inception. The University has provided the stable, special environment that has enabled the laboratories to make many remarkable scientific achievements and vital contributions to national security. In 2003, the Department of Energy (DOE) announced its intention to open the management of Los Alamos to full competition at the expiration of the current contract. Subsequent congressional legislation required that the management contracts for all three UC-managed national laboratories be subject to open competition.

Selected to lead the competition team, Michael Anastasio will become director of Los Alamos National Laboratory when the new contract begins in June 2006.

In April 2005, DOE awarded a new five-year contract to UC to manage and operate the Lawrence Berkeley National Laboratory. In May, the University announced that Livermore director Michael Anastasio would lead a team—the Los Alamos National Security LLC, or LANS—to compete for the Los Alamos contract. Partners in LANS are Bechtel National, Inc., UC, BWX Technologies, Inc., and the Washington Group International, Inc. Anastasio continued to serve as director of Livermore during the competition. In December, DOE Secretary Samuel W. Bodman announced the selection of LANS as the management and operations contractor for Los Alamos National Laboratory. The transition to LANS management is under way, and the new contract begins on June 1, 2006.

The UC contract to manage and operate Livermore has been extended to September 30, 2007. The UC Board of Regents has not made a final decision whether to compete for the Livermore contract, but it has authorized the University to begin preparations for the competition. As UC President Robert Dynes stated in January 2006, “Should we compete, we will do so vigorously and with the firm belief that excellence in science and technology is critical to the mission of the Laboratory.”

Laboratory Management Changes

Departures from the Director’s Office set the stage for the introduction of a new leadership team for the Laboratory in early 2006. Director Michael Anastasio left to lead LANS, and Wayne Shotts, deputy director for Operations, retired in January 2006 after 31 years of service to the Laboratory.

In March 2006, George Miller was selected interim director of the Laboratory by the UC Board of Regents. He is expected to serve through the remainder of the University’s current contract to manage the Laboratory. In his 34-year career at Livermore, Miller worked as a nuclear weapons designer for 12 years before being appointed deputy associate director for Nuclear Design in 1984. Since then he has served as associate director for a range of directorates, including Defense Systems, Nuclear Design,

When Energy Secretary Samuel W. Bodman (second from left) visited NIF in August, he was joined by (from left) George Miller, now director; Michael Anastasio; and NIF associate director Ed Moses.

National Security, Defense and Nuclear Technologies, and the National Ignition Facility; most recently, he was associate director at large. Miller also spent a year in Washington, D.C., as special scientific advisor on weapons activities to the secretary of Energy.

Appointments during 2005 brought many new faces into the Laboratory's senior management team. Ed Moses became associate director for National Ignition Facility (NIF) Programs after acting in that position when George Miller became associate director at large in May 2005. Prior to the appointment, Moses served as project manager for NIF. Later in May, Linda Rakow, with almost 20 years of service to the Laboratory, was named chief financial officer for Livermore. In June, Ray Juzaitis was named to lead the Nonproliferation, Arms Control, and International Security Directorate, and Melissa M. Allain became the Laboratory counsel. Juzaitis brings to the directorate 28 years of experience in nuclear weapons design and defense technologies from positions at Los Alamos and Livermore. Allain comes to Livermore from Tyco Fire & Security, where she served as chief compliance counsel.

The management team will build on planning activities—including the Aurora Project in 2005 and a senior management special meeting in early 2006—which developed the Laboratory's *A List* of priorities for the coming year. In addition, the Strategic Program Board and the Performance Assurance Board, consisting of key senior managers, were formed to assist the director in setting goals, formulating strategies, and overseeing the execution of high-priority institutional initiatives.

Attention to Workforce Management

The Laboratory established a Workforce and Communications Working Group with institutional oversight to ensure that Livermore retains and continues to attract the talent it needs for the future. Special emphasis is being given to effective management of recruitment and retention challenges that may arise during the upcoming competition for a new contractor to manage the Laboratory. At the same time, Livermore is working toward creating a more diverse and inclusive workplace. Exciting career opportunities and an inclusive, collegial work environment are key to effective recruitment and retention.

Ongoing activities with UC campuses (see p. 43) and other major research universities act as a pipeline to fulfill ongoing needs for critical skills and greater diversity. One of many special opportunities for graduate and undergraduate students is the Department of Homeland Security (DHS) Scholars and Fellows Program, which places outstanding young scholars at national laboratories for 10 weeks during the summer. Of the 105 award recipients in 2005, 25 students identified Lawrence Livermore as their first-choice laboratory. Altogether, Livermore is host to over 500 summer students who work side by side with Laboratory scientists.

The Laboratory's continuing success also depends on developing future leaders. Livermore's comprehensive programs aimed at leadership and management development are recognized as among the "best in class" within the UC system and the DOE complex. The core program includes two training courses for supervisors, a Management Institute designed to help prepare next-generation leaders, and a variety of short courses. Nearly 1,800 supervisors have been trained to date, and there are 150 alumni of the Management Institute, a two-and-a-half-day program presented by Laboratory senior managers. In addition, more than 740 employees have participated in customized leadership development programs in the Laboratory's directorates.

Livermore uses staff feedback to improve leadership development programs, and improved database systems are helping

Then-Laboratory director Michael Anastasio (left) and Representative Ellen Tauscher (10th District, California, center) visited with DHS interns, who spent the summer working alongside Laboratory scientists.

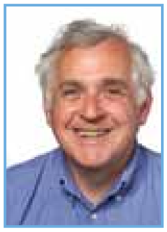
Laboratory management gauge success. Tracking data, for example, indicates that programs are reaching an increasingly diverse pool, positioning more women and minorities to become supervisors and future Livermore leaders. In addition, nearly 50 Laboratory employees each year participate in diversity leadership programs, including American Management Association Leadership Training for African Americans, Latino Leadership and Development, and Leadership Education for Asian Americans. In partnership with the Museum of Tolerance, the Laboratory has developed a unique program to help managers increase their interpersonal and cross-cultural competencies.

In 2005, the Laboratory completed the next steps in its Integrated Pay and Performance Program (IPPP). A newly restructured classification and pay system for administrative and specialist staff more closely aligns Laboratory pay with the marketplace. The classification system for management personnel was also redesigned. IPPP is the largest revision of Livermore's performance appraisal, ranking, and pay system in the last two decades. The program aims to be less complex than previous performance management approaches and to ensure greater consistency throughout the Laboratory.

People and Programs in the News

The scientific and technological accomplishments of Livermore employees are recognized by prizes, awards, and front-page publicity. But science isn't the whole story at Lawrence Livermore. Many other individuals and teams are also recognized for their contributions both inside and outside the Laboratory.

Laboratory scientists and engineers were responsible for 136 invention disclosures, 128 U.S. patent applications, 24 first foreign patent applications, 93 issued U.S. patents, and 14 issued foreign patents in fiscal year 2005.



Max Tabak (right), lead inventor of fast ignition for inertial confinement fusion (ICF), and Joseph Kilkenney, leader of the ICF program in 1995, were winners of the Edward Teller Medal. The American Nuclear Society lauded Tabak as an effective mentor and group leader, whose team has made major contributions to a range of topics in inertial confinement fusion and high-energy-density physics. Kilkenny is now vice president for Inertial Fusion Technology at General Atomics in San Diego and associate director for Science and Technology at the Laboratory for Laser Energetics of the University of Rochester.

Climate scientist Benjamin Santer won one of four

DOE Office of Biological and Environmental Research Program Distinguished Scientist fellowships.

Laboratory researchers garnered four R&D 100 awards among the 100 granted by *R&D Magazine* for the top industrial innovations worldwide. Livermore's total now stands at 106 awards since 1978. The 2005 awards were for:

• The Biological Aerosol Mass Spectrometer (BAMS), which can identify the presence and concentration of harmful biological particles in air samples.

• The Adaptable Radiation Area Monitor (ARAM), which can detect even small quantities of radioactive materials moving at either very slow speeds or in moving vehicles. Livermore shared the award with Innovative Survivability Technologies of Goleta, California.

• NanoFoil®, a nanoengineered heat source for lead-free soldering and brazing of materials at room temperature. Livermore, Reactive NanoTechnologies of Hunt Valley, Maryland, and Johns Hopkins University shared the award.

• VisIt, a visualization software tool for parallel processing of up to trillions of bytes of data.

The American Physical Society selected five Laboratory scientists as Fellows, including:

• John Moriarty, for his work on the first-principles quantum-based calculation of interatomic forces in d- and f-electron materials, with major impact on high-pressure physics, multiscale modeling, and national security.

• Carlos Iglesias, for the study of the production and transport of radiation in astrophysical and laboratory plasmas, including the development of the OPAL opacity code.

• Harry Radousky, for contributions and scientific leadership in experimental condensed matter and materials physics, with particular emphasis on discoveries related to optical materials, superconductivity, and high-pressure research.

• Vasily Bulatov, for efforts in computational materials science, particularly in the areas of dislocation dynamics and crystal plasticity.

• Joe Wong, for contributions to experimental materials physics, particularly for contributions to x-ray absorption measurement techniques, and for the first measurements of phonon dispersion in plutonium.

The California Section of the American Physical Society has named a student award for Laboratory physicist Kennedy Reed. The Kennedy Reed Award for Best Theoretical Research was one of five new awards named after distinguished physicists known for their educational outreach. Reed has contributed significantly to the promotion of physics research and education in Africa.

A team of scientists from IBM and the Laboratory won the coveted 2005 Gordon Bell Prize for pioneering materials science simulations conducted on BlueGene/L, the world's fastest supercomputer (see p. 9).

The National Nuclear Security Administration (NNSA) honored three individual scientists and three teams with Weapons Excellence awards for work performed in 2004. The awardees were:

• Thomas Healy, who developed the certification roadmap for the W80-3 Program, which has become a model for future development plans.

• Omar Hurricane, for a computer model that led to the resolution of a long-standing weapons-physics uncertainty.

• Mordecai Rosen, for resolving puzzling nuclear test data anomalies.

• The Livermore Computing TSF Team, for completing the Terascale Simulation Facility and activating it early and on budget.

• The National Hydrotest Plan Team, for significantly increasing the efficiency of hydrodynamic tests.

• The Tilt-Pour Furnace Development Team, for a new plutonium pyrochemical approach that reduces transuranic waste by about 70 percent.

NNSA Weapons Excellence awards were also given for work performed in 2003 to:

• William McLean, for developing time-, temperature-, and pressure-dependent models for corrosion in nuclear weapon pits and secondaries.

• The JASPER planning and commissioning team. The first plutonium (Pu) shot on JASPER produced the highest measured shock pressure in Pu and ultimately the most accurate dynamic high-pressure data ever taken for Pu.

• The W62 Detonator Investigation Team from Livermore and Sandia national laboratories, which investigated detonator aging characteristics and developed and qualified new tests.

• The Piano Subcritical Experiment Team, for using the most complex diagnostics of any subcritical experiment to date.

• The Post-Shot Cleanup Team at Site 300's Contained Firing Facility, for meeting stringent safety requirements for the Chronic Beryllium Prevention Program during post-shot operations inside the test chamber.

ASM International awarded its 2005 Henry Marion Howe Medal to Bassem El Dasher for a paper entitled "Statistically Representative Three-Dimensional Microstructures Based on Orthogonal Observation Sections," which appeared in *Metallurgical and Materials Transactions A*. This work is benefiting the Yucca Mountain Project (see p. 29).

Jim Berryman was awarded the 2005 Maurice A. Biot Medal of the American Society of Civil Engineers for his contributions in poromechanics, granular materials, random composite media, tomography and inverse problems, and seismology.

The Society of Automotive Engineers honored William Pitz and Charles Westbrook with a 2003 Arch T. Colwell Merit Award. Their paper, "Effects of Oxygenates on Soot Processes in DI Diesel Engines: Experiments and Numerical Simulations," was co-authored with scientists at Sandia National Laboratories. The paper was one of 11 honored in 2005.

Two teams won Lawrence Livermore's annual Science and Technology awards, the Laboratory's highest award for achievement in science and technology. One group developed BAMS for real-time identification of biological hazards. The other award was for the NIF Early Light Campaign, which demonstrated the individual beam performance of the NIF laser and its utility to perform experiments.

The Alameda County Women's Hall of Fame lauded Computation associate director Dona Crawford as Outstanding Woman of the Year.

Veteran molecular biologist Jim Felton was reappointed by Governor Arnold Schwarzenegger to the Carcinogen Identification Committee of the State Science Advisory Board.

Tom Isaacs was one of only two non-Canadians that served on the Canadian Nuclear Waste Management Organization's Assessment Team, which analyzed options for disposition of Canada's spent nuclear fuel.

Mike Newman was presented with the Commander's Award for Civilian Service by the U.S. Army for his work during two stints in Iraq. The award citation commended Newman for exceptional service as lead systems engineer and architect for the Persistent Threat Detection System from February to November 2004.

The Laboratory's effort to eliminate waste received two Pollution Prevention awards from DOE/NNSA. One was related to the disposal of transuranic waste, and the other was for better characterizing the Laboratory's waste stream to reduce disposal costs (see p. 36).

A former DHS Scholar, Rahul Satija, was one of 32 Americans chosen to be Rhodes Scholars. While at Livermore, Satija worked with the pathogen bioinformatics team on smallpox analysis.

The Laboratory's Competition Shoot Team took top honors at the "Best of the West" Special Weapons and Tactics Competition. The event was a qualifying shoot for the World SWAT Competition.

Two former Ernest O. Lawrence fellows at the Laboratory received the 2004 Presidential Early Career Award for Scientists and Engineers. Wei Cai, now an assistant professor of mechanical engineering at Stanford University, was honored for work performed while he was at Livermore. Joel Ullom received the award for work performed after he left Livermore.

Three of the Laboratory's technical publications were honored at the 2004 Society of Technical Communication (STC) international competition. The *2003 Chemistry and Materials Science Annual Report* won a Distinguished Award. Two other documents each won an Excellence Award: the Chemistry and Materials Science Directorate's careers recruitment brochure and the Laboratory's monthly publication, *Science and Technology Review*.

A literacy program offered to multiethnic, low achieving 11th-grade students in Oakland, California, received the 2005 Pacesetter Award from the international board of STC. The program was started by Terry Gerrill and has been cosponsored since 1999 by the Laboratory and the East Bay Chapter of STC. The students learned how to extract their own DNA at the Edward Teller Education Center.

Paul Dickinson, president of Keep California Beautiful, received a special award honoring the Laboratory's support in the organization's campaign to promote litter abatement through volunteer projects and education.

Celeste Matarazzo and Rose O'Brien, along with Livermore teacher Janis Turner, completed a 3,815-mile bicycle trip across the United States. They raised more than $8,000 for the Tri-Valley's Hope Hospice.

After 21 days in a 38-foot sailboat racing across the Atlantic Ocean, Jaime Marian and three crew mates won the Rubicon Antigua Challenge, sailing from the Canary Islands off the coast of Africa to Antigua in the Caribbean. They finished eighth out of 18 boats overall in time, but they won the race because Marian's crew had the smallest boat and never motored throughout the 3,300 nautical miles.

Laboratory Budget

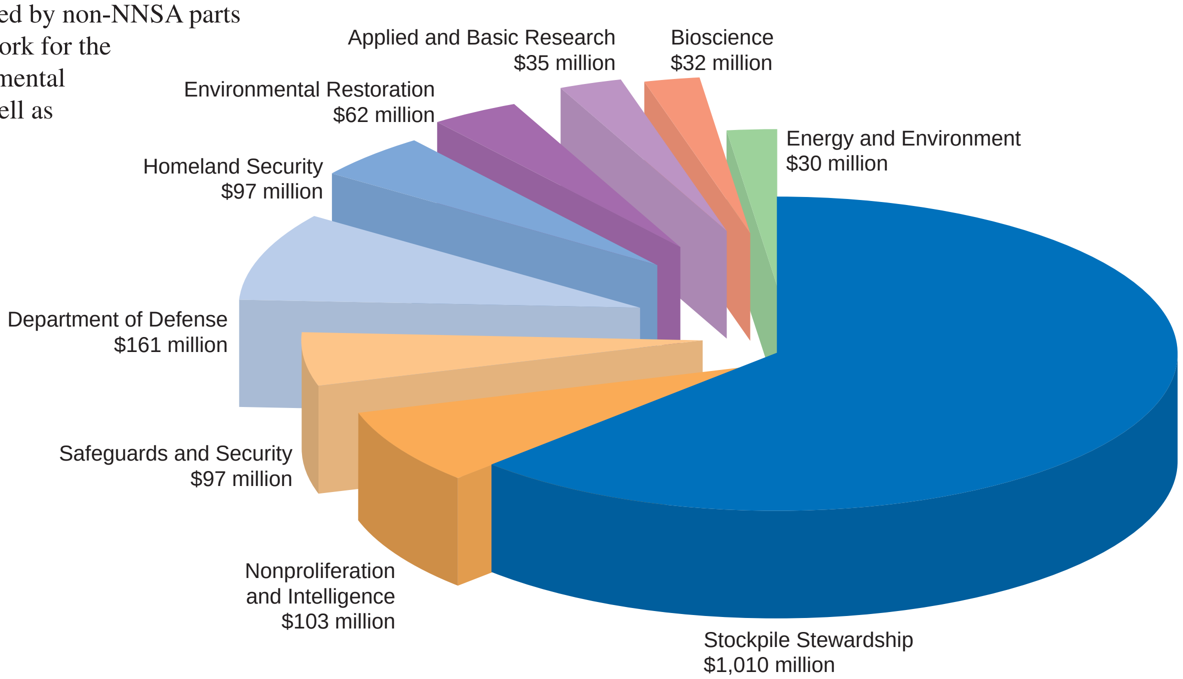
Most of Livermore's $1.63-billion budget for fiscal year 2005 was designated for research and development activities in program areas supporting DOE missions.

As a national security laboratory, Livermore is part of DOE/NNSA. The Laboratory's funding largely comes from the NNSA Office of Defense Programs for stockpile stewardship activities. Support for national security and homeland security work also comes from the NNSA Office of Defense Nuclear Nonproliferation, DHS, various Department of Defense sponsors, and other federal agencies.

As a multiprogram laboratory, Livermore applies its special capabilities to meet important national needs. Activities sponsored by non-NNSA parts of DOE include work for the Office of Environmental Management as well as research and development projects for the Office of Science and many other program offices. Non-DOE sponsors include federal agencies (such as the National Aeronautics and Space Administration, Nuclear Regulatory Commission, National Institutes of Health, and Environmental Protection Agency), State of California agencies, and industry.

Many of the Laboratory's research and development activities are pursued for sponsors as partnerships that combine special expertise and capabilities of the Laboratory with those of other DOE laboratories and research universities.

NNSA Administrator Linton Brooks speaks before a Laboratory audience during one of his visits to Livermore.



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Visit the Laboratory's Web site, http://www.llnl.gov/, for the latest news on scientific and technical developments. Our Public Affairs Office regularly posts news releases and science features on the site. Discover the many opportunities for employment, academic research, industrial partnerships, and fellowships.

Read about our accomplishments each month in our award-winning magazine, *Science and Technology Review*. The Laboratory's flagship publication is available on the Web, and you can use the Web site to order a free print subscription.

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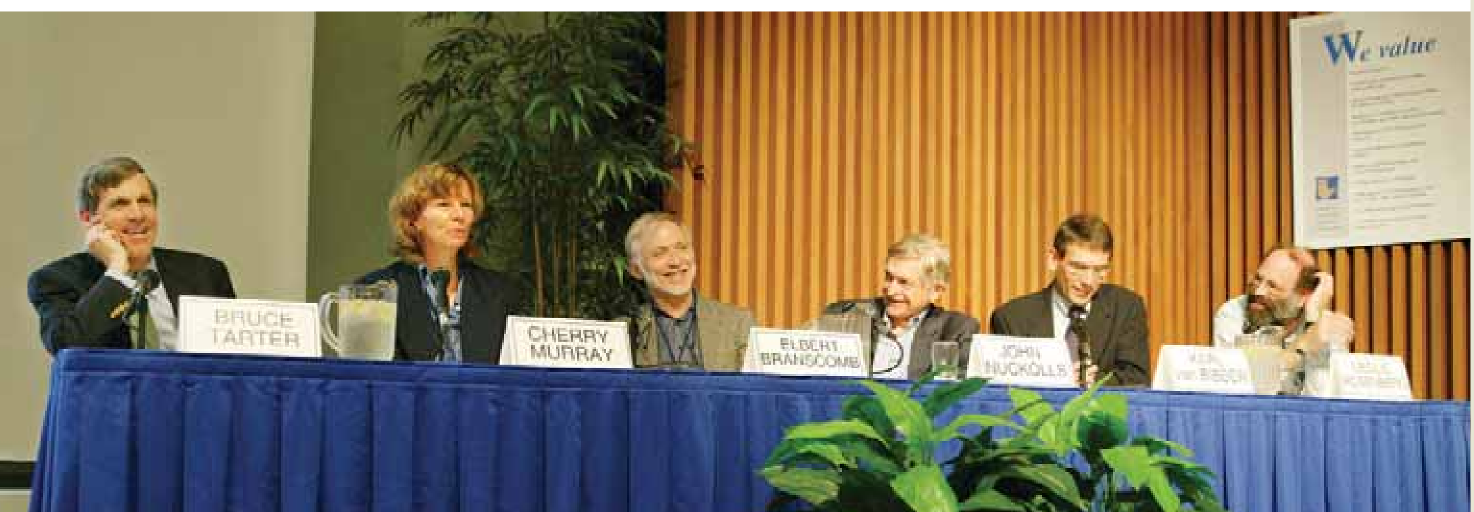
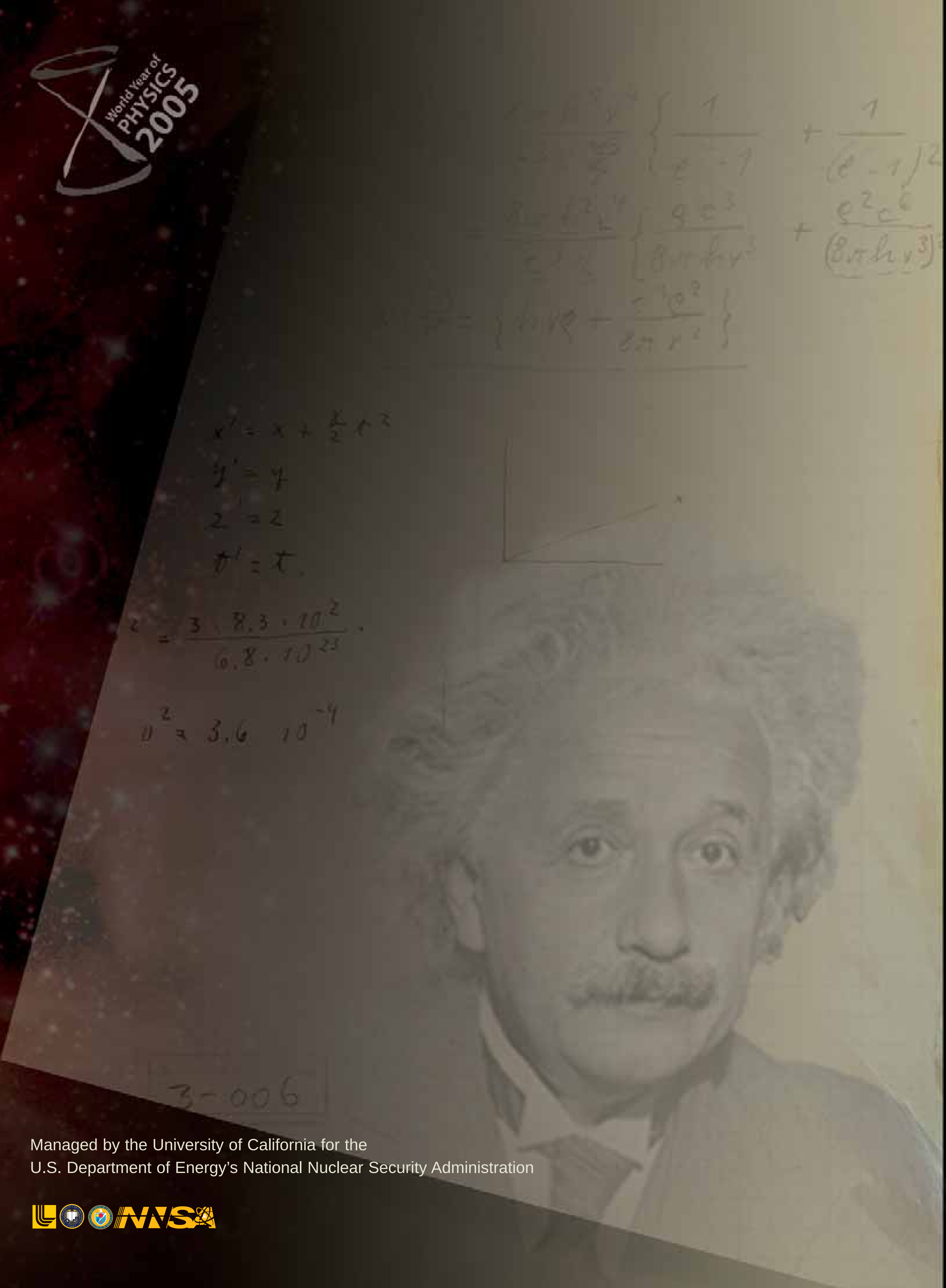


One event during Livermore's Week of Science was a discussion of the future of physics, in which current and former science leaders at the Laboratory looked at how the discipline might evolve over the next 20 years.



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